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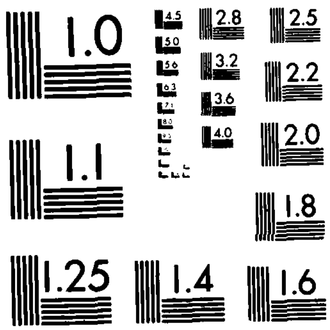
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Environmental Analysis of Lake Pontchartrain, Louisiana, Its Surrounding Wetlands, and Selected Land Uses

Volume 2

Edited by James H. Stone

Prepared for
U.S. Army
Engineer District,
New Orleans

Contract No
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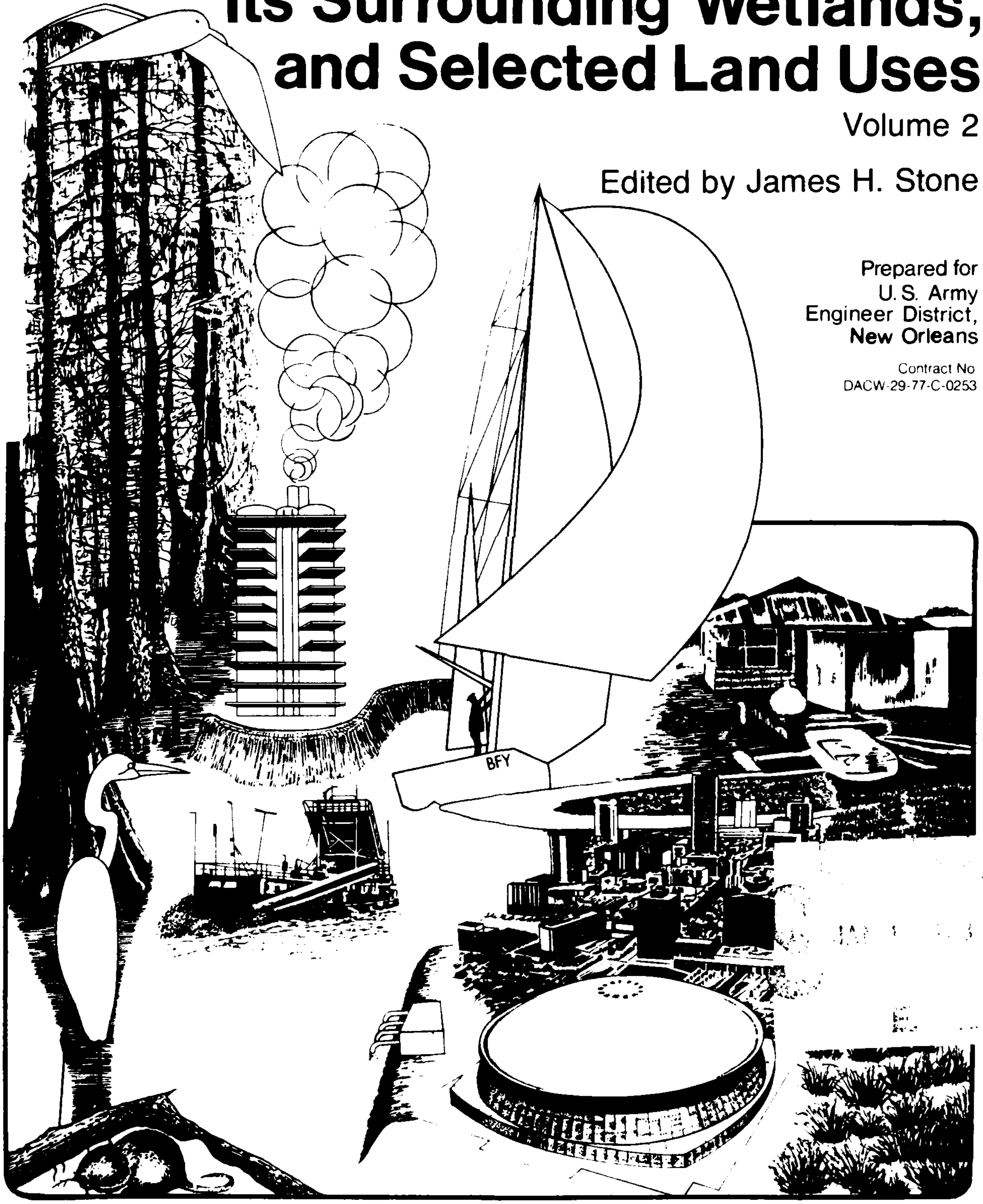

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The purpose of this research was to prepare an inventory and analysis of the environmental components in Lake Pontchartrain and the wetlands surrounding the lake in order to provide an information base and to indicate salient interactions, patterns, and environmental trends to facilitate future planning. Information regarding trophic state analysis, hydrology, hydrography, chemistry, plankton, nektom, and benthic distribution within the lake were analyzed. Life history and food habitat studies were conducted on 44 fish species found in Lake Pontchartrain. In addition, preliminary study of biological transport

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20. through the tidal passes within the Lake were addressed.

ENVIRONMENTAL ANALYSIS OF LAKE PONTCHARTRAIN, LOUISIANA, ITS SURROUNDING WETLANDS, AND SELECTED LAND USES

Volume 2

Edited by

James H. Stone
Coastal Ecology Laboratory
Center for Wetland Resources
Louisiana State University
Baton Rouge, Louisiana 70803

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Chapter 9

PRODUCTIVITY OF THE SWAMPS AND MARSHES SURROUNDING LAKE PONTCHARTRAIN, LOUISIANA

by

Glenn W. Cramer
and
John W. Day, Jr.

ABSTRACT

Net primary production was estimated in four marsh and two swamp sites in the wetlands surrounding Lake Pontchartrain, Louisiana, during 1978-1979. Live and dead aboveground biomass of *Spartina patens* was determined by the harvest method over an annual cycle. Litterbags were used to determine loss rates of dead vegetation from the marsh surface. Production estimates of *S. patens* using the Smalley (1958) method ranged from 2541 to 4411 g dry wt$\cdot$m$^{-2}\cdot$yr^{-1}; using the Wiegert and Evans (1964) method, production estimates ranged from 3056 to 5509 g dry wt$\cdot$m$^{-2}\cdot$yr^{-1}. Decomposition rates ranged from 34-55 percent litter removal after 6-8 months. General nutrient levels were also determined in the waters adjacent to the marsh sites. Vegetation transects showed *S. patens* to be the dominant marsh macrophyte in the brackish marshes and to have an average summer biomass of 2000-2500 g dry wt/m^2. *Sagittaria lancifolia* was the dominant freshwater marsh species and had an average biomass of 900 g dry wt/m^2.

Annual leaf litter-fall was 379 g dry wt/m^2 in a water tupelo swamp site and 567 g dry wt/m^2 in a baldcypress swamp site. Net primary production was 621 g dry wt$\cdot$m$^{-2}\cdot$yr^{-1} in the water tupelo site and 1097 g dry wt$\cdot$m$^{-2}\cdot$yr^{-1} in the baldcypress site.

INTRODUCTION

The coastal zone of Louisiana is an estuarine area of high natural productivity. It has been shown that this productivity is partially related to the extent and productivity of intertidal wetlands (Craig et al. 1979). The role of coastal wetlands in estuarine areas has been well documented (Teal 1962, Day et al. 1973, de la Cruz 1973, Odum and Heald 1975). The Lake Pontchartrain-Lake Borgne hydrologic unit of the Louisiana coastal zone contains approximately 64,000 hectares of brackish and intermediate salinity marsh wherein Spartina patens is the most abundant marsh macrophyte (68%-85% coverage) (Chabreck 1972). The Lake Pontchartrain basin also contains expanses of swamp forest dominated by two tree species, baldcypress (Taxodium distichum) and water tupelo (Nyssa aquatica) (Saucier 1963). The objective of this study was to measure the productivity of the marshes and swamps surrounding Lake Pontchartrain, Louisiana, using vegetation transects and water chemistry analysis.

MARSH PRODUCTIVITY

I. Description of Area

More complete area description of the Lake Pontchartrain basin, including geomorphology, climate, hydrology, and vegetation, can be found in Saucier (1963), Darnell (1958), Tarver and Savoie (1976), and Chabreck (1972).

Four marsh areas surrounding Lake Pontchartrain were selected for study (Fig. 1). Within each area, nearly pure stands of Spartina patens were chosen as sampling areas. The first site was located in the Goose Point marsh, adjacent to Bayou Lacombe. Drainage into the lake is through several natural tidal channels and breaks in the shore beach

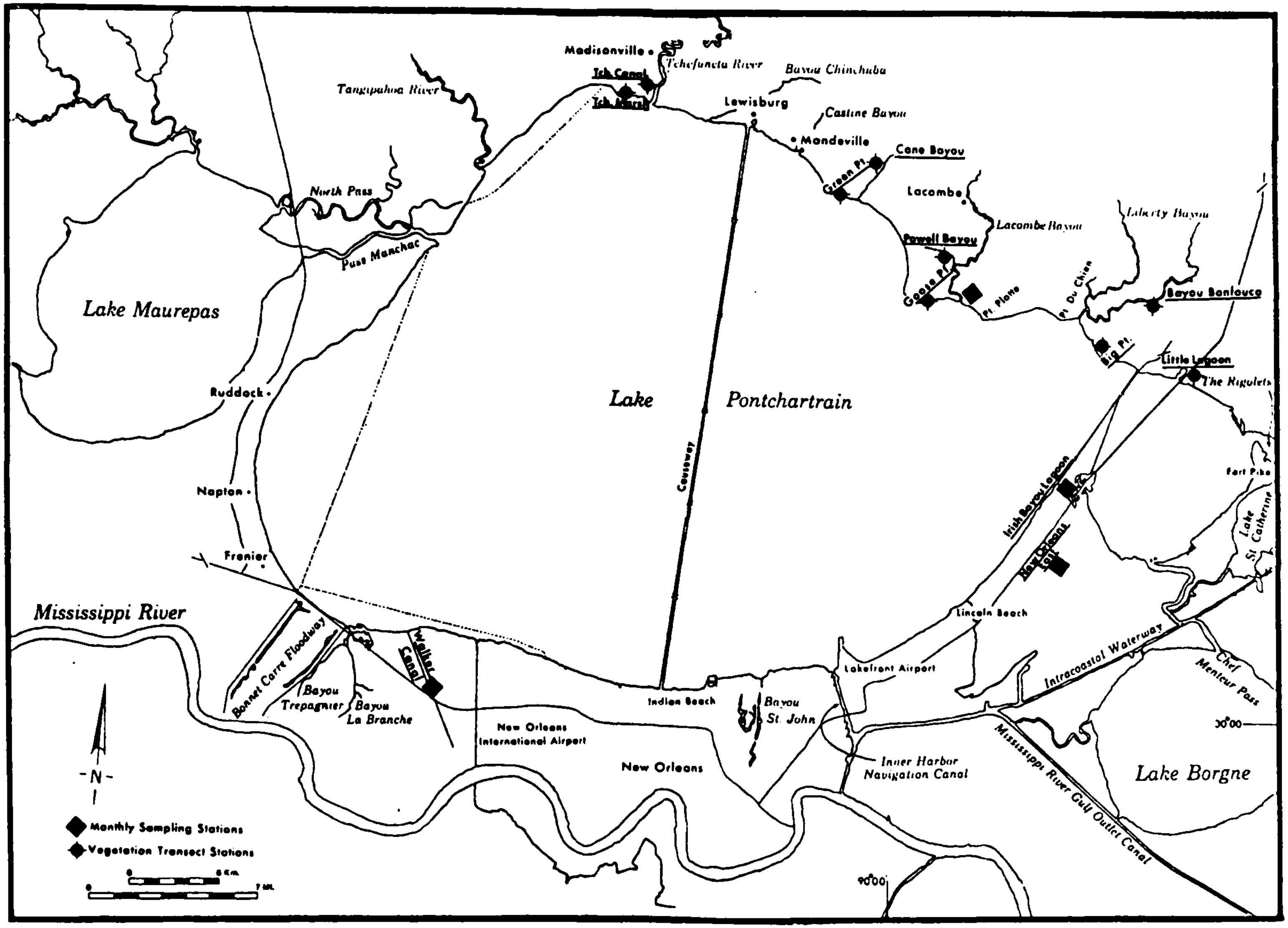


Figure 1. Map of study area showing monthly marsh sampling sites and August vegetation transect sampling sites in Lake Pontchartrain, LA, during 1978.

ridge. The area had been burned the previous year, and little dead vegetation remained on the marsh surface. Regrowth resulted in a dense stand of *S. patens* 1-1.5 m tall. The site was again burned by trappers after 10 months of study.

The second study site was located in the marsh adjacent to Irish Bayou Lagoon, east of Point aux Herbes. The site was open to natural tidal flushing and was covered by a dense, vigorous growth of *S. patens* 1-2 m tall. This marsh was also burned, which halted its study after 10 months.

The third marsh area was loc ed in the approximately 6000 hectares of impounded wetlands that comprise the New Orleans East region. The site was located east of the I-10 highway that traverses the wetland and was adjacent to a pipeline canal. The area has been almost completely impounded for 20 years and is not influenced by tidal flushing. Salinity in the impoundment is low (1 ppt or less) and in addition to wiregrass (*Spartina patens*), large stands of rush (*Juncus* spp.) and roseau cane (*Phragmites communis*) are located throughout the area. There were many small ponds and a large accumulation of dead material on the marsh surface. *S. patens* in the area averaged 70 cm in height.

The fourth site was located in the St. Charles Parish wetlands, adjacent to Walker Canal. Water exchange with the lake is via this canal. However, marsh elevation is high (15 cm), and tidal flushing in the area appears to be low. This is evidenced by the occurrence of *Baccharis halimifolia*, a high marsh species (Sasser 1977), in the area and by the large accumulation of dead vegetation on the marsh surface. Average height of *S. patens* at the site was 70 cm.

II. Materials and Methods

From February 1978 to March 1979, vegetation was harvested at three-to-six week intervals from five 0.1-m^2 quadrats chosen at random in each marsh site. Site selection and sampling routine were designed to ensure that no quadrat was resampled. The marsh grass was clipped at mud level, placed in bags, and taken to the lab. Dead material was also collected on the mud surface. Samples were then sorted into live (green) and dead stems, and the dead leaves were stripped from live culms. The grass was dried at 65°C for 48 hours and weighed. Primary production was then calculated using Smalley's (1958) method based on changes in live and dead standing crop between sampling times. If there is an increase in live standing crop, production during that interval is equal to that increase plus any increase in the dead standing crop. If the live standing crop decreases, production is equal to the algebraic sum of live and dead standing crop or zero, whichever is larger (Appendix 1-I).

To account for decompositional loss of dead material during sampling intervals, not considered in the Smalley method, the technique described by Wiegert and Evans (1964) was also used to calculate net primary production (Appendix 1-III). To determine rates of decomposition, 25 g of oven-dried _S. patens_ was placed in nylon litterbags with 2 mm mesh. Sixty bags were staked in each marsh site on June 20, 1978, and five were removed at every harvest sampling. Bags were returned to the lab; washed of debris, mud, and organisms; dried at 65°C for 48 hours; and weighed. An instantaneous loss rate of g lost · g dead vegetation^{-1}·time^{-1} was calculated from litterbag weight loss during each sampling period, and production was calculated using the equations derived by Wiegert and Evans

(1964) (Appendix 1-11). The Wiegert and Evans equations assume uniform increases or decreases in live and dead biomass over time. However, experimental data contain fluctuations associated with sampling error and environmental variation. In order to account for these two factors, standing crop and loss rate data were fitted to fourth order polynomial regression curves for use in Wiegert and Evans calculations (Kirby and Gosselink 1976; White et al. 1978).

III. Results

A. Decomposition

Table 1 contains the monthly instantaneous loss rates, calculated from litterbag loss in the four marsh sites, used in the Wiegert and Evans productivity calculations. Litterbag loss rates were graphed in terms of percent of material remaining over time (Fig. 2). The Goose Point and Irish Bayou sites showed similar decomposition rates; with 66% remaining (34% removal) after six months (Table 2). The New Orleans East site had 47% remaining (53% removal) after eight months. Decomposition rates were highest in the Walker Canal marsh, with 45% remaining (55% removal) after 8 months (Table 2). Marsh burning ended litterbag sampling in the Goose Point and Irish Bayou sites after six months.

B. Standing Crop

Live standing crop in the Goose Point marsh increased from February to an October peak of 2130 g/m^2 (Fig. 3). Dead standing crop showed a trend of gradual increase from April to December (Fig. 3). Live standing crops in the Irish Bayou marsh rose from February to peak in September at 2466 g/m^2 (Fig. 4). Dead material showed erratic fluctuations throughout sampling and had a winter maximum. Sampling in these two areas was prematurely ended after December by marsh burning.

Table 1. Monthly Instantaneous Loss Rates for Lake Pontchartrain, LA, 1978 Calculated as Proportion of Mass at Beginning of Month Using Experimental and Predicted Data (g lost·g dead vegetation^{-1}·month^{-1})

Date	Marsh Area							
	Goose Point		Irish Bayou		New Orleans East		Walker Canal	
start: 6/20/78	Experimental	Predicted	Experimental	Predicted	Experimental	Predicted	Experimental	Predicted
7/12/78	0.106	0.106	0.084	0.084	0.151	0.152	0.114	0.112
8/9/78	0.092	0.102	0.084	0.087	0.101	0.101	0.112	0.129
9/19/78	0.125	0.090	0.121	0.113	0.098	0.094	0.179	0.121
10/17/78	0.075	0.070	0.051	0.060	0.048	0.069	0.030	0.057
11/10/78	0.005	0.007	0.012	0.009	0.092	0.055	0.000	0.036
12/9/78	0.306	0.006	0.048	0.048	0.012	0.063	0.147	0.057
1/23/79	Burned		Burned		0.116	0.077	0.034	0.116
3/2/79	Burned		Burned		0.091	0.099	0.129	0.114
	$r^2 = 0.99$		$r^2 = 0.99$		$r^2 = 0.79$		$r^2 = 0.43$	

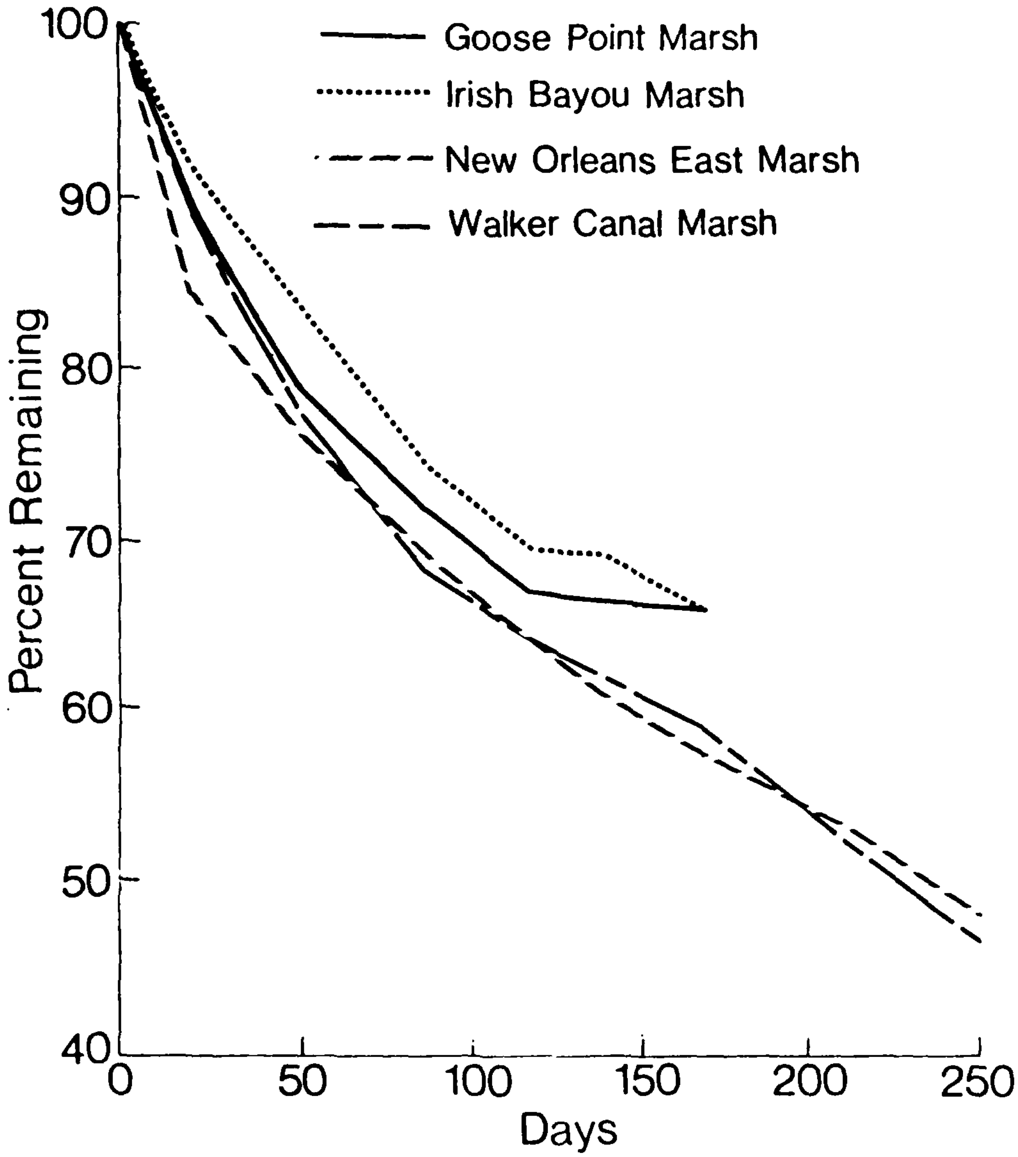


Figure 2. Percent litter remaining over time in Lake Pontchartrain, LA, 1978, calculated using predicted instantaneous loss rates.

Table 2. Percent Litter Remaining Over Time in Lake Pontchartrain, LA, Calculated Using Experimental and Preducted Instantaneous Litterbag Loss Rates

Days in field start 6/20/78	Marsh Area							
	Goose Point		Irish Bayou		New Orleans East		Walker Canal	
	Experimental	Predicted	Experimental	Predicted	Experimental	Predicted	Experimental	Predicted
20	89.4	89.4	91.6	91.6	84.6	84.8	88.6	88.8
48	81.2	78.7	83.9	83.6	76.0	76.2	78.8	77.4
87	71.0	71.6	73.8	74.2	68.6	69.0	64.6	68.0
117	65.7	66.6	70.0	69.6	65.3	64.3	62.7	64.1
140	65.4	66.1	69.2	69.1	59.3	60.7	62.7	61.8
170	65.0	65.7	65.8	65.8	58.6	56.8	53.5	58.3
213	Burned		Burned		51.8	52.5	51.7	51.5
251	Burned		Burned		47.1	47.3	45.0	45.6

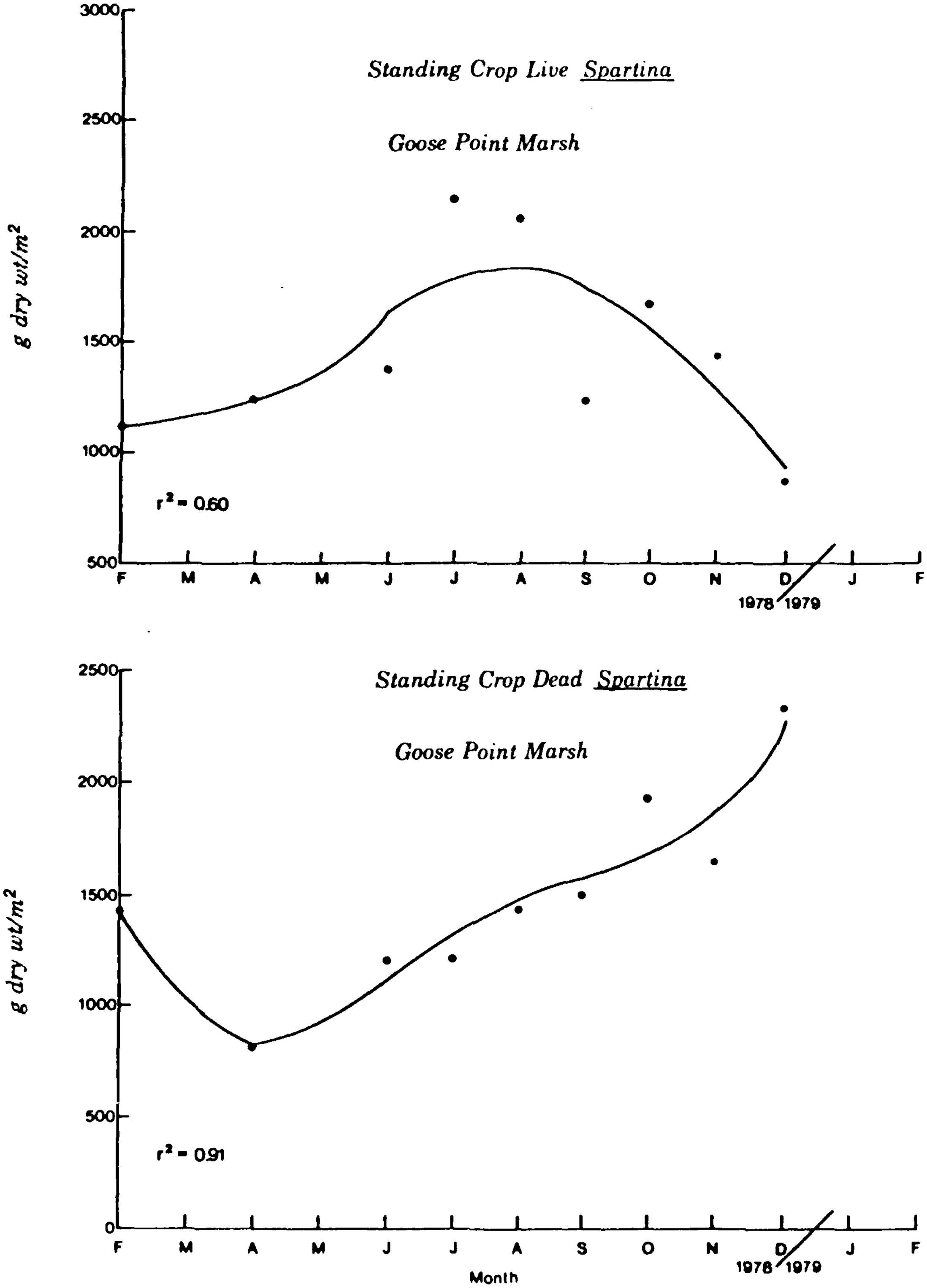


Figure 3. Standing crop of live and dead Spartina patens in the Goose Point marsh area.

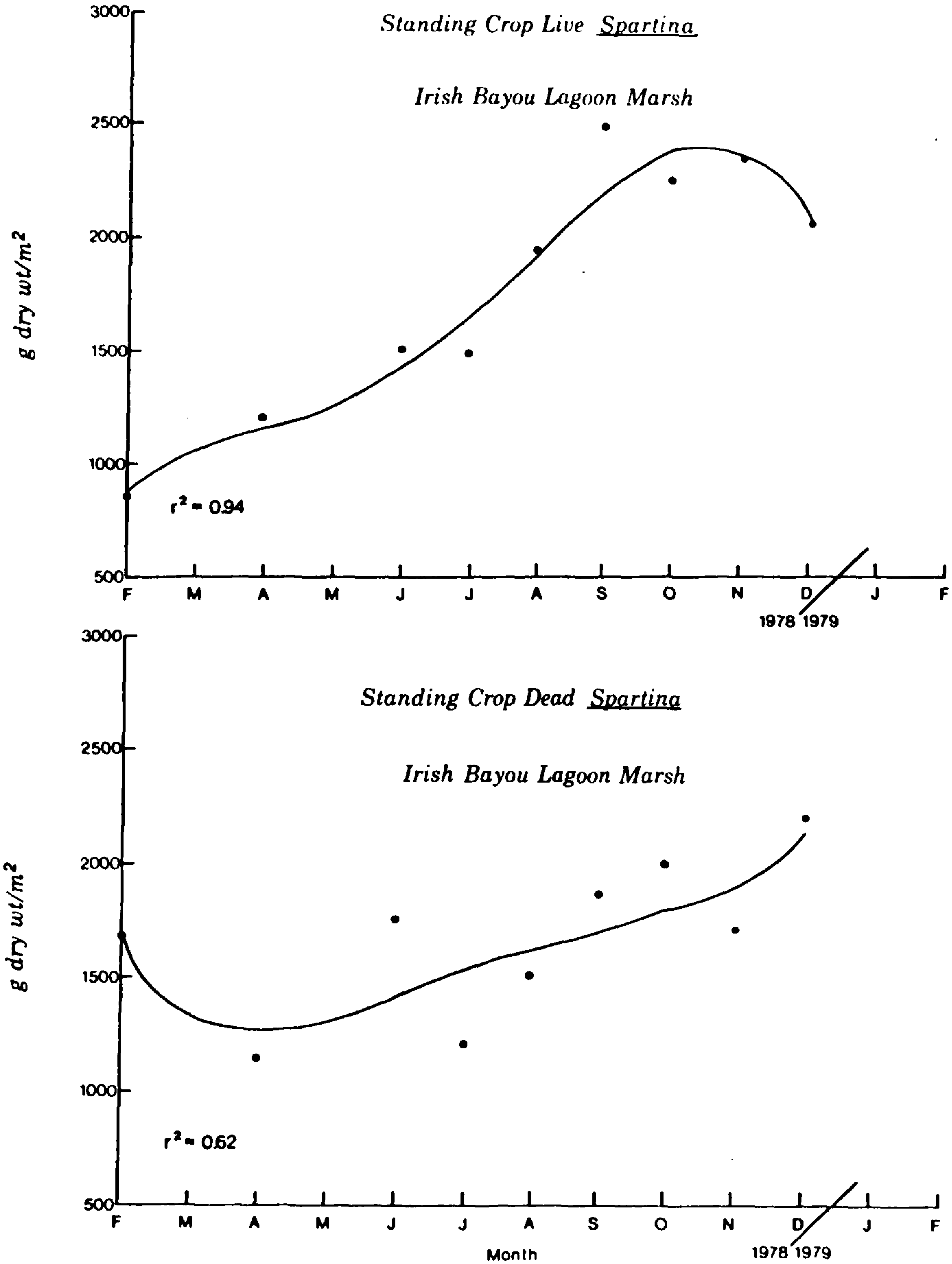


Figure 4. Standing crop of live and dead Spartina patens in the Irish Bayou Lagoon marsh area of Lake Pontchartrain, LA, in 1978-1979.

Live standing crop in the New Orleans East marsh rose from an extreme low in February to peak in October at 1248 g/m^2 (Fig. 5). Dead standing crop showed spring and winter peaks (Fig. 5). Live standing biomass in the Walker Canal marsh showed a trend of gradual increase from February to a November peak of 2159 g/m^2 (Fig. 6). Dead standing crop fluctuated widely throughout the study year (Fig. 6).

Sampling variability, expressed as the ratio of the standard error to the mean x 100, ranged from 7 to 37% and averaged 16% for monthly standing crop estimates. These sampling errors are within reasonable limits for a field study of this type (Wiegert and McGinnis 1975; Hopkinson et al. 1978).

C. Net Production

Smalley Method--Experimental data were used to calculate production values by the Smalley method. It was assumed that because the Goose Point and Irish Bayou marshes were burned in late winter, when production is lowest, the 10-month production estimates for those two areas closely reflect annual production. Net primary production using the Smalley method were 2541, 3192, 2605, and 4411 $g \cdot m^{-2} \cdot yr^{-1}$ in the Goose Point, Irish Bayou, New Orleans East, and Walker Canal marshes, respectively (Table 3).

Wiegert and Evans Method--Net primary production using predicted data and the Wiegert and Evans equations was 2087, 2861, 3056, 3464 $g \cdot m^{-2} \cdot yr^{-1}$ in the Goose Point, Irish Bayou, New Orleans East, and Walker Canal marshes, respectively (Table 3).

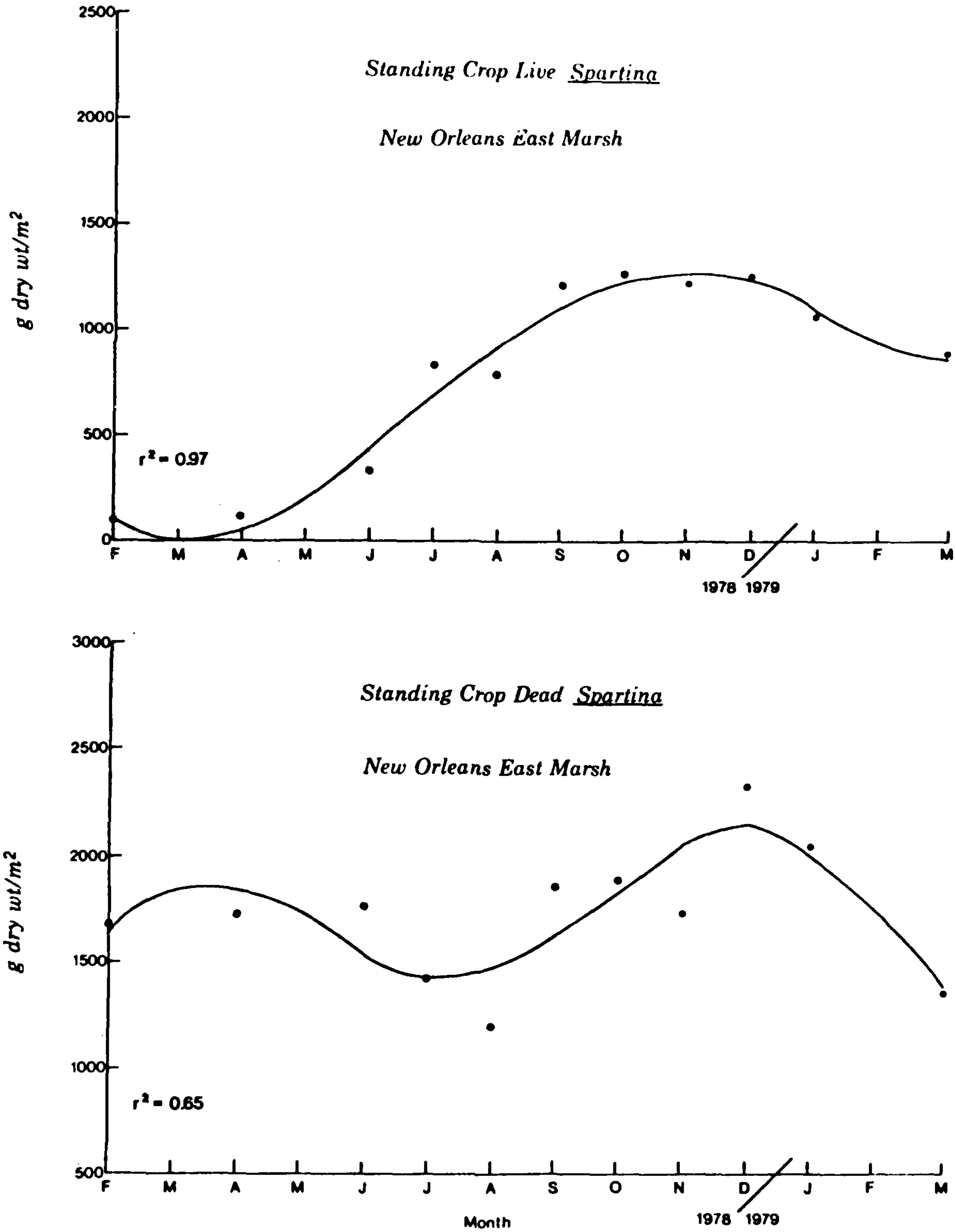


Figure 5. Standing crop of live and dead Spartina patens in the New Orleans East marsh area of Lake Pontchartrain, LA, in 1978-1979.

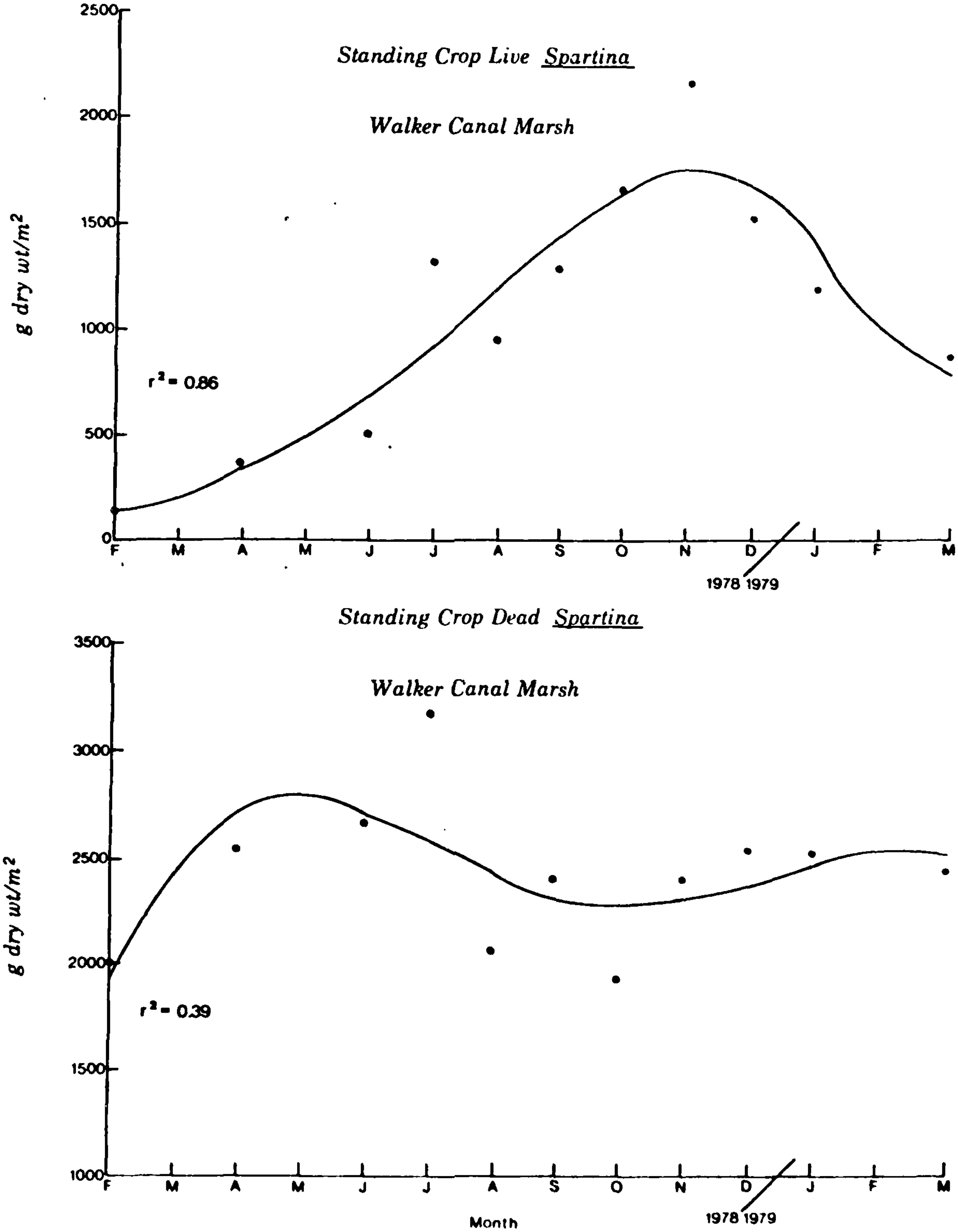


Figure 6. Standing crop of live and dead *Spartina patens* in the Walker Canal marsh area of Lake Pontchartrain, LA, in 1978-1979.

Table 3. Production Values ($g \cdot m^{-2} \cdot yr^{-1}$) for the Four Lake Pontchartrain Marsh Sites Using the Smalley Method with Experimental Data and the Wiegert and Evans Method with Predicted Experimental Data

Method	Marsh Area			
	Goose Point	Irish Bayou	New Orleans East	Walker Canal
Smalley (experimental)	2541	3192	2605	4411
Wiegart & Evans (predicted)	2087	2861	3056	3464
Wiegart & Evans (experimental)	3075	3595	3053	5509

IV. Discussion

Detailed analysis and comparison of the merits and use of the Smalley (1958) and Wiegert and Evans (1964) methods of estimating plant production can be found in Turner (1976), Kirby and Gosselink (1976), and White et al. (1978). In general, the Smalley method is considered to underestimate net aerial production (Turner 1976). The Wiegert and Evans method is considered to be more accurate because it accounts for loss of dead material as well as for changes in live and dead standing crop (Kirby and Gosselink 1976, White et al. 1978). It seems logical that when adding another component to productivity estimates (i.e., litter decomposition), production figures would increase. However, in this study, the Wiegert and Evans technique yields, production values lower than the Smalley method in all but one case (Table 3). Use of predicted or curve fit data in the Wiegert and Evans method calculations is probably the major reason for this discrepancy. Reasons for using predicted data are discussed by Kirby and Gosselink (1976); however, they also point out that fitted curves do not adequately reflect some of the real fluctuations in standing crop. This seems to be the case for data from this study (Figs. 3-6). Therefore, Wiegert and Evans production estimates were also calculated using experimental data. Results with experimental data yielded net annual production values (g/m^2) of 3075, 3595, 3053, and 5509 for the Goose Point, Irish Bayou, New Orleans East, and Walker Canal marshes, respectively (Table 3). From field observations and data manipulation, it was concluded that these figures more accurately represent true annual production than those generated using predicted data.

MARSH VEGETATION TRANSECTS

I. Introduction

During the month of August 1978, vegetation harvest transects were made at nine locations in the marshes surrounding the north shore of Lake Pontchartrain. Sampling sites included marsh areas ranging from just west of the Tchefuncte River mouth to Little Lagoon near The Rigolets (Fig. 1).

II. Materials and Methods

At each marsh site, five 0.1-m^2 vegetation plots were harvested at approximately 20-m intervals progressing away from the lake shoreline. This was done to include changes in marsh vegetation through possible salinity and elevation gradients. Harvested vegetation was separated by species, bagged, and a sample was pressed for identification. The bagged material was then oven dried at 65°C for 48 hours and weighed. No attempt was made to separate live from dead vegetation.

III. Results

A list of the plant species harvested at each marsh site and their average August biomass is presented in Table 4. *Spartina patens* was by far the most abundant marsh macrophyte collected. Total average biomass (mostly live material) consistently ranged from 2000 to 2500 g dry wt/m^2 in the marshes and was composed primarily of *S. patens* (Tchefuncte, Green Point, Cane Bayou, Goose Point, and Bayou Bonfouca marshes). The Little Lagoon marsh was 90% *S. patens*, but growth was stunted by a marsh fire early in the spring. The perturbation caused by the fire was also evidenced by the relatively large number of plant species that populated the area during regrowth. Average August live biomass in the monthly sampling

Table 4. Plant Species Composition and Biomass Estimates for Lake Pontchartrain, LA, North Shore Marshes from Vegetation Transects, During 1978

Plant Species	Tchefuncte Marsh		Tchefuncte Canal		Green Point		Cane Bayou		Goose Point	
	Average Biomass g dry wt/m^2	% Total Biomass	Average Biomass g dry wt/m^2	% Total Biomass	Average Biomass g dry wt/m^2	% Total Biomass	Average Biomass g dry wt/m^2	% Total Biomass	Average Biomass g dry wt/m^2	% Total Biomass
Spartina patens	3410	96.5	----	----	2280	93.3	1820	78.6	2105	97.5
Scirpus olneyi	----	----	----	----	163	6.7	42	1.8	27	1.3
Sagittaria lancifolia	123	3.5	756	82.0	----	----	358	15.5	----	----
Juncus effusus	----	----	----	----	----	----	----	----	----	----
Polygonum punctatum	----	----	113	12.3	----	----	----	----	----	----
Eleocharis spp.	----	----	12.6	1.4	----	----	51	2.2	----	----
Aster subulatus	----	----	19.8	2.1	----	----	43	1.9	----	----
Lippia nodiflora	----	----	6.8	0.7	----	----	----	----	----	----
Cyperus compressus	----	----	----	----	----	----	----	----	25	1.2
Cyperus haspan	----	----	4.2	0.5	----	----	----	----	----	----
Lythrum lineare	----	----	----	----	----	----	----	----	----	----
Sabatia dodecandra	----	----	----	----	----	----	----	----	----	----
Fimbristylis castanea	----	----	----	----	----	----	----	----	----	----
Unidentified grasses	----	----	8.0	0.9	----	----	----	----	----	----
Average Total Biomass g dry wt/m^2	Live 2525 Dead 1000		920.0		2443		2314		2157	

Table 4. Continued

Plant Species	Sampling Area							
	Bayou Powell		Bayou Bonfounca		Big Point		Little Lagoon	
	Average Biomass g dry wt/m^2	% Total Biomass	Average Biomass g dry wt/m^2	% Total Biomass	Average Biomass g dry wt/m^2	% Total Biomass	Average Biomass g dry wt/m^2	% Total Biomass
Spartina patens	----	----	2421	99.3	657	48.6	847	90.8
Scirpus olneyi	----	----	18	0.7	693	51.4	----	----
Sagittaria lancifolia	402	57.3	----	----	----	----	----	----
Juncus effusus	226	26.3	----	----	----	----	----	----
Polygonum punctatum	141	16.4	----	----	----	----	----	----
Eleocharis spp.	----	----	----	----	----	----	----	----
Aster subulatus	----	----	----	----	----	----	----	----
Lippia nodiflora	----	----	----	----	----	----	10	1.0
Cyperus compressus	----	----	----	----	----	----	----	----
Cyperus haspan	----	----	----	----	----	----	13	1.4
Lythrum lineare	----	----	----	----	----	----	----	----
Sabatia dodecandra	----	----	----	----	----	----	8	0.8
Fimbristylis castanea	----	----	----	----	----	----	10	1.0
Unidentified grasses	----	----	----	----	----	----	39	4.2
							5	0.5
Average Total Biomass g dry wt/m^2	858		2439		1350		933	

sites, primarily S. patens, was 2000 g dry wt/m^2 in Goose Point and Irish Bayou and 1000 g dry wt/m^2 in the Walker Canal and New Orleans East marshes.

The fresh marsh areas (Tchefuncte Canal and Bayou Powell) were composed mainly of Sagittaria lancifolia and had an average biomass of approximately 900 g dry wt/m^2. These areas also exhibited the highest species diversity. The Big Point marsh was composed of one-half Spartina patens and one-half Scirpus olneyi, which resulted in an intermediate average biomass of 1400 g dry wt/m^2. Table 5 is a species list of all those plants either harvested or encountered in abundance during the transect study.

IV. Discussion

Lake Pontchartrain's north shore wetlands were characterized by brackish and intermediate marshes composed primarily of Spartina patens adjacent to the shoreline that graded into fresh marshes and primarily of Sagittaria lancifolia at higher elevations near the swamp forest. Average summer biomass of the dominant vegetation types seemed to be consistent throughout the range of marsh areas. The brackish marshes exhibited higher biomass and lower diversity than the freshwater marshes.

MARSH WATER CHEMISTRY

I. Materials and Methods

Water samples were collected at the four marsh study sites to determine general nutrient levels and indicate water quality. Samples were taken eight times during the study year in 500-ml plastic bottles, 20-30 cm below the surface. Samples were collected from canals or bayous adjacent to the marsh, not from waters overlying the marsh surface, which

Table 5. Plant Species List of Lake Pontchartrain North Shore Marshes from Vegetation Transects During 1978-1979

Scientific Name	Common Name
Ammannia coccinea	Ammannia
Aster subulatus	Aster
Alternanthera philoxeroides	Alligator weed
Bacopa monnieri	Water hyssop
Cladium jamaicense	Sawgrass
Cyperus compressus	Cyperus
Cyperus haspan	Cyperus
Distichlis spicata	Saltgrass
Echinochloa walteri	Walter's millet
Fimbristylis castanea	Saltmarsh fimbristylis
Hypericum spp.	St. John's wort
Ipomoea sagittata	Saltmarsh morning glory
Iva frutescens	Marsh elder
Juncus effusus	Soft rush
Lythrum lineare	Loosestrife
Myrica cerifera	Wax myrtle
Panicum virgatum	Panic grass
Phragmites australis	Roseau cane
Lippia nodiflora	Common frog-fruit
Pluchea camphorata	Saltmarsh pluchea
Polygonum punctatum	Smartweed
Sabatia dodecandra	Sabatia
Sagittaria lancifolia	Duck potato
Scirpus olneyi	Three corner grass
Scirpus robustus	Leafy threesquare
Sesbania exaltata	Coffee weed
Spartina cynosuroides	Hogcane
Spartina patens	Wiregrass

is periodically flooded or dry. After collection, 500-ml each of raw and filtered (0.45μ) water from each site were quick frozen on dry ice. Samples were then transported to the laboratory and kept frozen until analysis. Samples were assayed for NH_4^+ -N, $(NO_3^{-3} + NO_2^- + NH_4^+)$ -N, Kjeldahl-N, PO_4^{3-} -P, and Total P according to the methods of Strickland and Parsons (1968), with specific modifications as outlined in Ho and Schneider (1976).

II. Results

Nutrient concentrations in each marsh area are listed in Tables 6-9 and summarized in Table 10. NH_4 + -N averaged 0.1 mg/l or less in all four areas. Average $(NO_3 + NO_2)$ -N concentrations were low (0.06 mg/l or less) in the Goose Point, Irish Bayou, and New Orleans East areas but were significantly higher (0.26 mg/l) in the Walker Canal area ($P < .05$). Average organic -N concentrations were equal and lowest (0.62 mg/l) in the Goose Point and Irish Bayou areas, intermediate (0.96 mg/l) in the Walker Canal area, and highest (1.87 mg/l) in the New Orleans East area. Organic -N values closely followed those of total -N in all four areas, averaging 90% of all nitrogen assayed. Approximately 70% of the organic nitrogen assayed was in the dissolved form. Dissolved organic nitrogen accounted for 90% of the total dissolved nitrogen fraction. Total -N followed the same pattern as organic -N in the four marsh areas, averaging 0.69, 0.65, 1.94, and 1.20 mg/l in the Goose Point, Irish Bayou, New Orleans East, and Walker Canal sites, respectively.

Average orthophosphate -P levels were equal and lowest (0.01 mg/l) in the Goose Point and Irish Bayou marshes, intermediate (0.09 mg/l) in the New Orleans East area, and highest (0.14 mg/l) in the Walker Canal

Table 6. Nutrient Chemistry Data From the Gosse Point Marsh Area (mg/l)

Date	NH_4^+-N	$(NO_3^- + NO_2^-)$-N	Dissolved organic -N	Total dissolved -N	Organic -N	Total -N	PO_4^{-3}-P	Total -P	DOC	TOC
2/13/78	0.07	0.10	0.26	0.33	0.44	0.61	0.02	0.03	9.1	14.2
4/24/78	0.03	0.04	0.36	0.39	0.50	0.57	0.00	0.09	---	---
6/1/78	0.01	0.02	0.56	0.59	0.68	0.70	0.01	0.05	4.5	5.5
7/12/78	0.00	0.01	0.48	0.49	0.86	0.87	0.00	0.07	10.2	11.5
8/9/78	0.03	0.01	0.27	0.30	0.69	0.72	0.01	0.11	8.2	9.5
9/19/78	0.08	0.06	0.42	0.56	0.55	0.69	0.00	0.04	6.9	7.1
10/17/78	0.01	0.05	---	---	---	---	0.00	0.04	11.3	12.5
12/10/78	0.01	0.03	---	---	---	---	0.00	0.02	8.1	9.9
$\bar{x}$	0.03	0.04	0.39	0.44	0.62	0.69	0.01	0.06	8.3	10.0
s	0.03	0.03	0.12	0.12	0.15	0.10	0.01	0.03	2.2	3.0
$s_{\bar{x}}$	0.01	0.01	0.05	0.05	0.06	0.04	0.00	0.00	0.8	1.1

Table 7. Nutrient Data from the Irish Bayou Lagoon Marsh Area (mg/l)

Date	NH_4^+-N	$(NO_3^-+NO_2^-)$-N	Dissolved organic -N	Total dissolved -N	Organic -N	Total -N	PO_4^{-3}-P	Total -P	DCC	TOC
2/13/78	0.06	0.00	0.33	0.38	0.67	0.73	0.00	0.05	14.4	14.4
4/24/78	0.35	0.00	0.16	0.20	0.50	0.53	0.00	0.09	---	---
6/1/78	0.00	0.00	0.35	0.36	0.59	0.59	0.02	0.07	2.1	7.4
7/12/78	0.00	0.01	0.42	0.44	0.62	0.64	0.02	0.06	6.5	7.4
8/9/78	0.01	0.01	0.24	0.26	0.41	0.43	0.02	0.04	6.5	8.4
9/19/78	0.01	0.04	0.43	0.48	0.58	0.63	0.01	0.04	6.5	7.4
10/17/78	0.05	0.01	0.44	0.49	0.63	0.68	0.03	0.04	5.6	7.1
12/10/78	0.01	0.07	0.42	0.50	0.90	0.98	0.01	0.15	6.6	10.0
$\bar{X}$	0.06	0.02	0.35	0.39	0.61	0.65	0.01	0.07	6.4	8.9
s	0.12	0.02	0.10	0.11	0.14	0.16	0.01	0.04	3.7	2.6
$s_{\bar{x}}$	0.04	0.01	0.04	0.04	0.05	0.06	0.00	0.01	1.4	1.0

Table 8. Nutrient Chemistry Data for the New Orleans East Marsh Area (mg/l)

Date	NH_4^+-N	$(NO_3^-+NO_2^-)$-N	Dissolved organic -N	Total dissolved -N	Organic -N	Total -N	PO_4^{-3}-P	Total -P	DOC	TOC
2/13/78	0.08	0.00	0.88	0.96	1.00	1.08	0.01	0.04	11.5	15.1
4/24/78	0.04	0 00	1.17	1.21	1.84	1.88	0.13	0.19	---	---
6/1/78	0.01	0.04	1.53	1.56	1.68	1.73	0.16	0.24	18.7	20.6
7/12/78	0.04	0.03	1.83	1.90	1.87	1.93	0.09	0.21	22.4	23.9
8/9/78	0.05	0.06	1.95	2.06	2.35	2.46	---	---	23.3	23.3
9/19/78	0.07	0.05	1.99	2.11	2.16	2.28	0.07	0.16	22.5	23.5
10/17/78	0.03	0.05	2.10	2.18	2.16	2.24	---	---	22.3	23.8
12/10/78	0.31	0.26	---	---	---	---	0.08	0.13	17.0	17.6
$\bar{X}$	0.08	0.06	1.64	1.71	1.87	1.94	0.09	0.16	19.7	21.1
s	0.10	0.83	0.46	0.48	0.45	0.46	0.05	0.07	4.3	3.5
$s_{\bar{x}}$	0.03	0.03	0.17	0.18	0.17	0.17	0.02	0.03	1.6	1.3

Table 9. Nutrient Chemistry Data for the Walker Canal Marsh Area (mg/l)

Date	NH_4^+-N	$(NO_3^-+NO_2^-)$-N	Dissolved organic -N	Total dissolved -N	Organic -N	Total -N	PO_4^{-3}-P	Total -P	DOC	TOC
2/13/78	0.25	0.68	0.92	1.17	1.14	2.07	0.08	0.14	12.5	14.8
4/24/78	0.42	0.79	---	---	---	---	0.07	0.28	---	---
6/1/78	0.00	0.00	0.57	0.57	0.83	0.83	0.24	0.33	7.4	9.9
7/12/78	0.03	0.00	1.46	1.49	1.59	1.62	0.39	0.57	16.2	18.2
8/9/78	0.00	0.23	0.33	0.37	0.71	0.74	0.06	0.11	9.0	11.5
9/19/78	0.03	0.13	0.49	0.64	0.72	0.87	0.06	0.11	7.4	8.4
10/17/78	0.09	0.16	0.56	0.80	0.85	1.09	0.14	0.24	7.8	8.8
12/10/78	0.00	0.28	0.74	1.04	0.89	1.18	0.05	0.15	11.8	12.6
$\bar{x}$	0.10	0.26	0.72	0.87	0.96	1.20	0.14	0.24	10.3	12.1
s	0.15	0.31	0.37	0.39	0.31	0.48	0.12	0.16	3.3	3.5
$s_{\bar{x}}$	0.05	0.11	0.14	0.15	0.12	0.18	0.04	0.06	1.3	1.3

Table 10. Average Annual Nutrient Concentrations in the Four Marsh Study Sites (mg/l)

Study area	NH_4^+-N	$(NO_3^-+NO_2^-)$-N	Dissolved organic -N	Total dissolved -N	Organic -N	Total -N	PO_4^{-3}-P	Total -P	DOC	TOC
Goose Point	0.03	0.04	0.39	0.44	0.62	0.69	0.01	0.06	8.3	10.0
Irish Bayou	0.06	0.02	0.35	0.39	0.62	0.65	0.01	0.04	6.9	8.9
New Orleans East	0.08	0.06	1.64	1.71	1.87	1.94	0.09	0.16	19.7	21.0
Walker Canal	0.10	0.26	0.72	0.87	0.96	1.20	0.14	0.24	10.3	12.1

marsh. Total -P averaged 0.06, 0.04, 0.16, and 0.24 mg/l in the Goose Point, Irish Bayou, New Orleans East, and Walter Canal marsh areas, respectively.

Total organic carbon concentrations averaged 10.0 mg/l in the Goose Point marsh, 8.9 mg/l in the Irish Bayou marsh, 21.1 mg/l in the New Orleans East marsh, and 12.1 mg/l in the Walker Canal marsh area. Dissolved organic carbon levels closely followed those of Total Oxygen Concentration (TOC) in all four areas, averaging 87% of all organic carbon assayed.

III. Discussion

No significant differences in average nutrient levels were found between the Goose Point and Irish Bayou marsh areas ($P < .05$). The lack of difference indicates possible correlations between water sources and environmental factors affecting water quality in those areas. In contrast, organic and total nitrogen levels in the New Orleans East marsh area were significantly higher than those observed in the Goose Point, Irish Bayou, and Walker Canal sites ($P < .05$). The large difference in nitrogen levels may be attributed to the lack of water flow and tidal flushing in the New Orleans East marsh caused by impoundment. Nutrients are released into the water column. If they are not rapidly recycled, they probably build up and maintain high levels in the impounded waters. The high rate of turnover and sediment uptake of phosphate, characteristic of most aquatic ecosystems (Stumm and Leckie 1970, Patrick and Khalid 1974), could account for the absence of high phosphorous concentrations in the impound d New Orleans East waters. Dissolved and total organic carbon levels were also significantly higher in the New Orleans East marsh than in the other three areas ($P < .05$). Impoundment of the marsh

area could prevent the characteristic export of dissolved and particulate organic matter from both live and decaying Spartina spp. (Turner 1978) and result in the higher concentrations observed in the New Orleans East site.

Nitrate-nitrite-N and orthophosphate -P levels were significantly higher in the Walker Canal marsh area than in the other three areas ($P < .05$). Similar inorganic nutrient levels for the same area were reported by Cramer (1978), who also reported the possibility of nutrient inputs to the marsh from upland drainage. Nutrient loading from upland runoff, not evidenced in the Goose Point, Irish Bayou, or New Orleans East sites, could account for the higher concentrations observed in Walker Canal.

SWAMP PRODUCTIVITY

I. Description of Area

Two swamp sites were studied in the Lake Maurepas-Lake Pontchartrain basin. The first site was located north of Louisiana Interstate 10, 3.2 km west of the I-10:Blind River Bridge in St. James Parish (Fig. 7). It is part of the large area of water tupelo swamp southeast of Lake Maurepas that drains into Lake Pontchartrain. As a result of intensive logging, very little mature baldcypress now remains. Original vegetation in the area has been replaced by thickets of black willow and buttonbush mixed with baldcypress and water tupelo (Saucier 1963). Local relief does not usually exceed 30 cm. (maximum elevations 0.6 to 0.9 m), and the study area was continually flooded during sampling.

The second swamp study site was located in St. Charles Parish adjacent to the Good Hope Oil and Gas field (Fig. 7). The area is

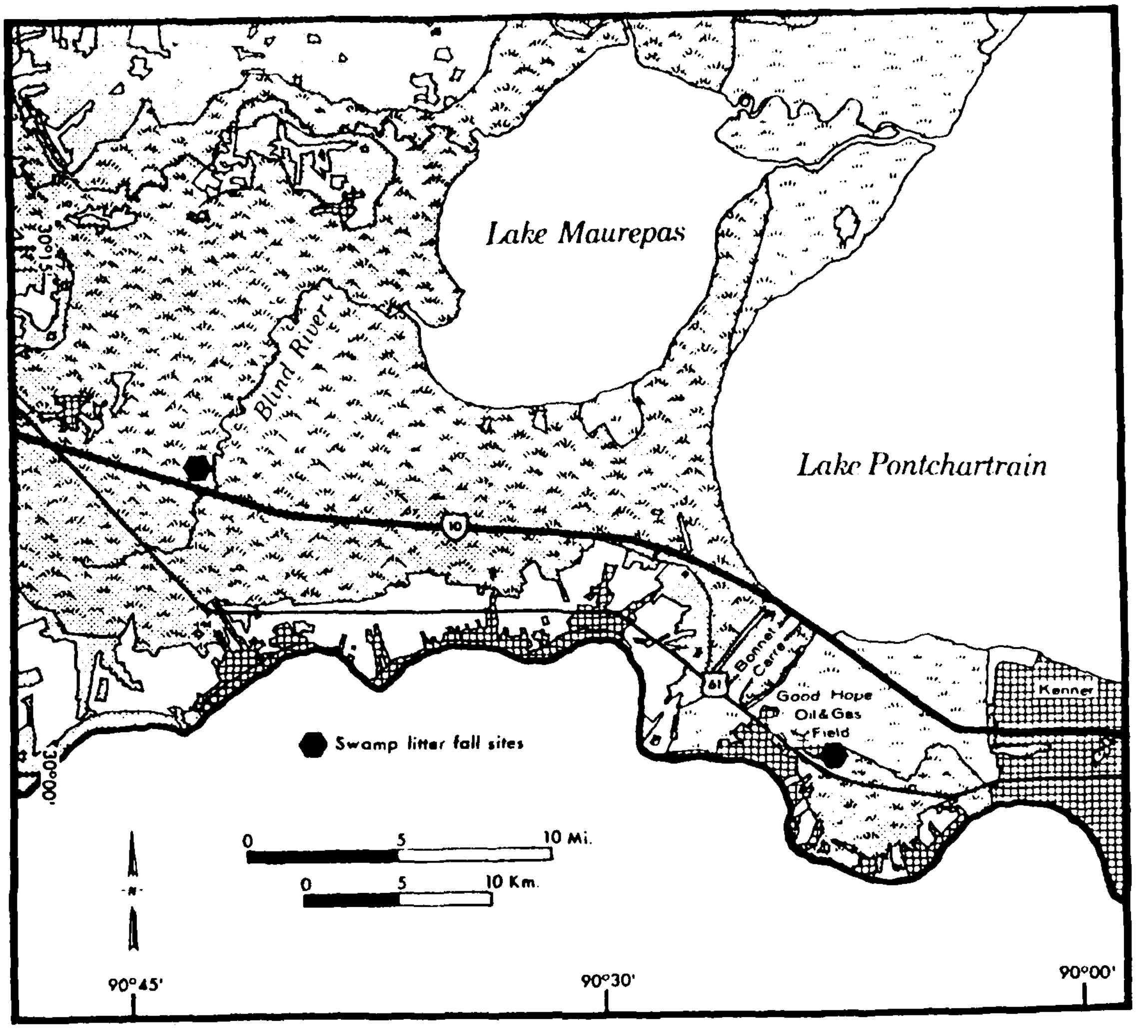


Figure 7. Map of swamp study sites of Lake Pontchartrain, LA.

separated from the nearby oil and gas well heads by an access road and appeared to be unaffected by the oil and gas extraction activities. The area is characterized by approximately 5.5 thousand hectares of backswamp that is comprised predominately of baldcypress (La. Dept. Hwys. 1977). Since the construction of the Illinois Gulf Central Railroad in the mid 1800's, baldcypress in the area has extended its range from the fresh-water backswamp into the adjacent marsh (Montz and Cherubini 1973). Swamp elevation is 1.5 meters or less above mean sea level (MSL) with drainage into Lake Pontchartrain through Bayou LaBranche and Crossbayou Canal (Cramer 1978).

II. Materials and Methods

A. Litter-Fall

Study plots 1000 m^2 (0.1 hectare) were selected in each swamp area. Litter-fall was collected every three to six weeks from April 1978, to March 1979, in 10 1-m^2 litter traps randomly placed in each plot. The litter boxes were constructed with reinforced window screen bottoms, 10-cm sides, and 1-m legs to prevent flooding of trapped litter. Collected litter was separated into woody (twigs and bark) and non-woody (leaves and flowers) components, dried at 65°C for 24 hours, and weighed.

B. Transects

The point-centered quarter method (Ashby 1972) was used to determine tree species composition in each swamp area. Absolute frequency, absolute density, average diameter at breast height (DBH), and importance values (IV) were calcualted for each tree species (Mueller-Dombois and Ellenberg 1974) (Appendix 2-III).

C. Biomass and Production

Biomass and stem production estimates for baldcypress were calculated using the equations of Schlesinger (1976, 1978) (Appendix 2-1). Biomass and stem production estimates for all other species measured in the transects were calculated using the equations described by Monk (Monk et al. 1970) (Appendix 2-II). Total net primary production was calculated by summing the stem production and annual litter-fall estimates for each area.

III. Results

A. Transects

Transect results from the St. Charles Parish Swamp yielded only two tree species, baldcypress and Drummond red maple (Table 11). Baldcypress was by far the dominant species, with a 97.4% frequency (IV = 96), whereas Drummond red maple showed only a 2.6% frequency (IV = 4). Average DBH of the baldcypress was 26.0 cm. Four tree species were measured on the Blind River transect (Table 12). Water tupelo was dominant, with a frequency of 56.2% (IV = 60), followed by Drummond red maple (IV = 19), ash (IV = 16), and baldcypress (IV = 5). Average DBH of the baldcypress (35.2 cm) was almost 10 cm larger than the same species in the St. Charles swamp in contrast to the other three species, which ranged from 6.3 cm (Drummond red maple) to 22.0 cm (water tupelo). Absolute density of all species in the Blind River swamp (1844 stems/ha) was 2.3 times higher than in the St. Charles swamp (793 stems/ha). Species lists of all vegetation encountered on the swamp transects are recorded on Tables 13 and 14.

Table 11. Species Characteristics of the St. Charles Parish Swamp Site Boardering the Southeast Shore of Lake Pontchartrain, LA, from Transects Taken During 1978

Common / Scientific name	Absolute frequency (% occurrence)	Absolute density (stems/ha)	Average DBH (cm)	Total basal area (m^2/ha)	Importance values (basis of 100)
Baldcypress *Taxodium distichum*	97.4	772	25.9	44.2	95.9
Drummond red maple *Acer drummondii*	2.6	21	4.70	0.04	4.1

Table 12. Species Characteristics of the Blind River Swamp Site Near Lakes Maurepas and Pontchartrain, LA, from Transects Taken During 1978

Common / Scientific name	Absolute frequency (% occurrence)	Absolute density (stems/ha)	Average DBH (cm)	Total basal area (m^2/ha)	Importance values (basis of 100)
Water tupelo *Nyssa aquatica*	56.2	1037	22.0	49.5	60.09
Drummond red maple *Acer drummondii*	23.8	438	6.3	1.71	19.01
Ash *Fraxinus* spp.	17.5	323	11.3	3.69	15.78
Baldcypress *Taxodium distichum*	2.5	46	35.2	4.55	5.10

Table 13. Plant Species List for the St. Charles Parish Swamp Site Near Lake Pontchartrain, LA, in 1978

Scientific Name	Common Name
Trees and Shrubs	
Acer rubrum var. drummondii	Drummond red maple
Baccharis halimifolia	Groundsel-tree
Cephalanthus occidentalis	Buttonbush
Fraxinus spp.	Ash
Myrica cerifera	Wax myrtle
Rubus spp.	Blackberry
Sabal minor	Palmetto
Taxodium distichum	Baldcypress
Vines	
Ampelopsis arborea	Peppervine
Mikania scandens	Climbing hempweed
Herbs and Other Plants	
Alternanthera philoxeroides	Alligator weed
Boehmeria cylindrica	False nettle
Cabomba caroliniana	Fanwort
Echinodorus cordifolius	Creeping burhead
Hydrocotyle verticillata	Whorled pennywort
Hymenocallis occidentalis	Spiderlily
Iris spp.	Iris
Lemna spp.	Duckweed
Limnobium spongia	American frogbit
Lycopus rubellus	Water-horehound
Panicum spp.	Panic grass
Phytolacca americana	Pokeweed
Polygonum punctatum	Smartweed
Pontederia cordata	Pickerelweed
Scutellaria lateriflora	Maddog skullcap
Solanum americanum	Nightshade
Solidago spp.	Goldenrod
Tillandsia usneoides	Spanish moss
Wolffia spp.	Water-meal
Woodwardia virginica	Virginia chain fern

Table 14. Plant Species List for the Blind River Swamp Site Near Lakes Maurepas and Lake Pontchartrain, LA, in 1978

Scientific Name	Common Name
Trees and Shrubs	
Fraxinus spp.	Ash
Itea virginica	Virginia willow
Myrica cerifera	Wax myrtle
Nyssa aquatica	Water tupelo
Nyssa sylvatica var. *biflora*	Swamp blackgum
Rubus spp.	Blackberry
Taxodium distichum	Baldcypress
Herbs and Other Plants	
Boehmeria cylindrica	False nettle
Cabomba caroliniana	Fanwort
Cyperus spp.	Sedge
Echinodorus cordifolius	Creeping burhead
Eichhornia crassipes	Water hyacinth
Hydrocotyle verticillata	Whorled pennywort
Iris spp.	Iris
Lemna spp.	Duckweed
Limnobium spongia	American frogbit
Lobelia cardinalis	Cardinal flower
Lycopus rubellus	Water-horehound
Myriophyllum brasiliense	Parrotfeather
Onoclea sensibilis	Sensitive fern
Osmunda regalis	Royal fern
Pistia stratiotes	Water lettuce
Polygonum punctatum	Smartweed
Polypodium polypodioides	Resurrection fern
Pontederia cordata	Pickerelweed
Riccia spp.	Aquatic liverwort
Scutellaria laterifolia	Maddog skullcap
Smilax spp.	Greenbriar
Utricularia spp.	Bladderwort
Wolffiella spp.	Wolffiella
Woodwardia virginica	Virginia chain fern

B. Litter-Fall

The patterns of litter-fall in the two swamps were dissimilar. Liter-fall in the St. Charles swamp peaked in December at 6.8 g dry $wt \cdot m^{-2} \cdot day^{-1}$ (Fig. 8). Litter accumulation in the Blind River site showed two peaks: an early August peak characteristic of water tupelo swamps (William Conner, personal comm.) followed by a November peak, both at 3.5 g dry $wt \cdot m^{-2} \cdot day^{-1}$ (Fig. 9). Water tupelo trees in the Blind River swamp were almost totally defoliated by insect grazing in the month of April. Total annual litter-fall was 379 and 567 g dry $wt \cdot m^{-2} \cdot yr^{-1}$ in the Blind River and St. Charles swamps, respectively.

C. Biomass and Production

Standing tree biomass was estimated to be 36.2 and 27.8 kg/m^2 in the Blind River and St. Charles swamps, respectively. Differences in standing crop biomass can be attributed to the higher tree density in the Blind River swamp. Stem production was estimated to be 241.7 g dry $wt \cdot m^{-2} \cdot yr^{-1}$ in the Blind River site and 530.6 g dry $wt \cdot m^{-2} \cdot yr^{-1}$ in the St. Charles site. Total net primary production (sum of stem production and litter-fall) was calculated to be 621 g dry $wt \cdot m^{-2} \cdot yr^{-1}$ in the Blind River swamp and 1091 g dry $wt \cdot m^{-2} \cdot yr^{-1}$ in the St. Charles swamp (Table 15).

IV. Discussion

The total primary production figures do not take into account understory production and insect grazing and are therefore minimal estimates. Insect grazing (primarily by the forest tent caterpillar), most heavily affects water tupelo trees. They can be almost totally defoliated in large areas of southern swamps (Conner and Day 1976).

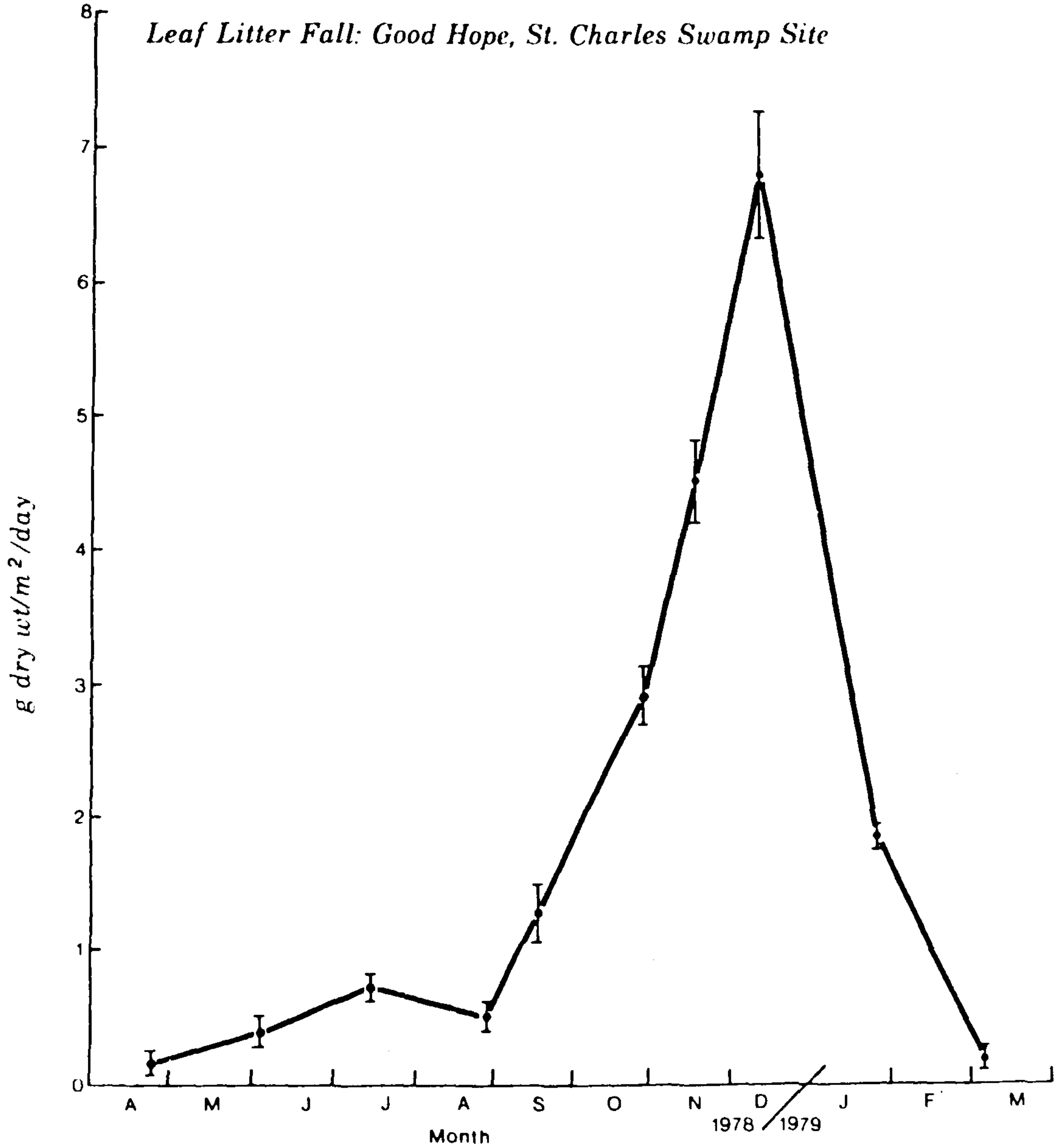


Figure 8. Litter-fall in the St. Charles Parish swamp site bordering the southeast shore of Lake Pontchartrain, LA, in 1978. Error bar is $\pm$ 2 x S.E. of the mean.

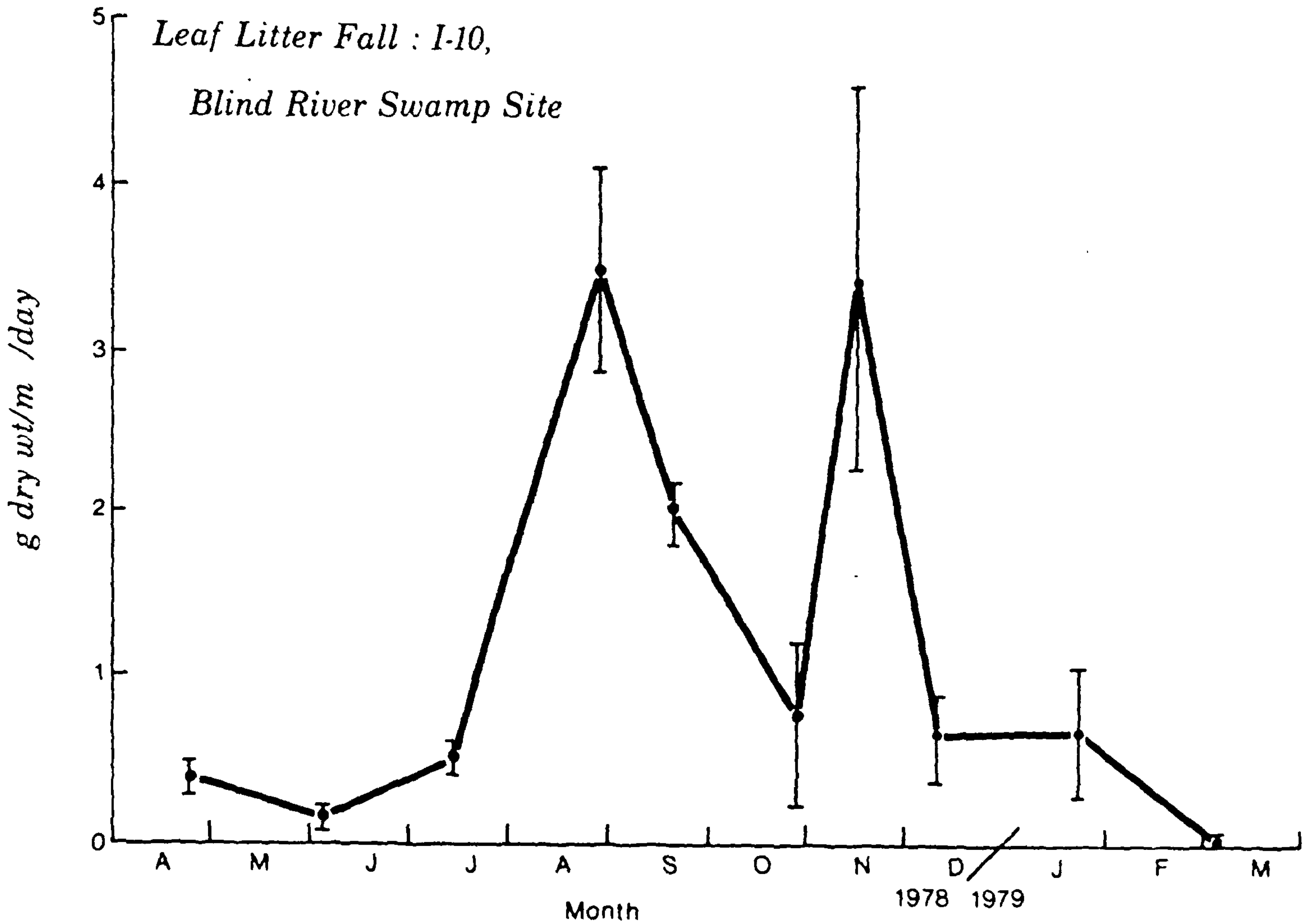


Figure 9. Litter-fall in the Blind River swamp site near Lakes Maurepas and Pontchartrain, LA, in 1978. Error bar is 2 x S.E. of the mean.

Table 15. Biomass, Litter-fall, and Productivity Values for the Blind River and St Charles Parish Swamp Sites Near the Southeast Shore of Lake Pontchartrain, LA, 1978

	Blind River	St. Charles Parish
Biomass[a] g dry wt/m^2	36,200	27,800
Litter-fall/day g dry wt.m^{-2}.day^{-1}	1.1	1.7
Total litter-fall g dry wt.m^{-2}.yr^{-1}	379	567
Stem biomass production g dry wt.m^{-2}.yr^{-1}[a]	242	530
Net primary productivity g dry wt.m^{-2}.yr^{-1}[b]	621	1097

[a]Estimated from transect data.

[b]Sum of total litter-fall and stem biomass production.

Production estimates in the St. Charles swamp correspond very well with figures reported by Conner and Day (1976) for a baldcypress-water tupelo swamp near Lac Des Allemands, Louisiana, and other southern swamp forests. They reported a stem production of 500 g dry $wt \cdot m^{-2} \cdot yr^{-1}$ and a total production of 1140 g dry $wt \cdot m^{-2} \cdot yr^{-1}$ in the Des Allemands swamp, as compared to the 530 and 1097 g dry $wt \cdot m^{-2} \cdot yr^{-1}$ production figures in the St. Charles swamp. The St. Charles Parish site, therefore, appears to be a relatively healthy and productive swamp forest area, typical of those found in Louisina. In contrast, production in the Blind River site (621 g dry $wt \cdot m^{-2} \cdot yr^{-1}$) was quite low compared to reported values for similar swamp types. Production was low compared to the productivity values of 1574 g dry $wt \cdot m^{-2} \cdot yr^{-1}$ reported by Conner and Day (1976). Low production in this area could be the result of earlier intensive logging and heavy insect grazing, as mentioned previously. In addition, studies of swamp productivity in southeastern United States (reviewed in Conner and Day 1976) indicate that seasonal flooding provides the optimum for tree growth and survival. Production is found to be lowest under continually flooded, low water flow conditions such as those observed in the Blind River swamp.

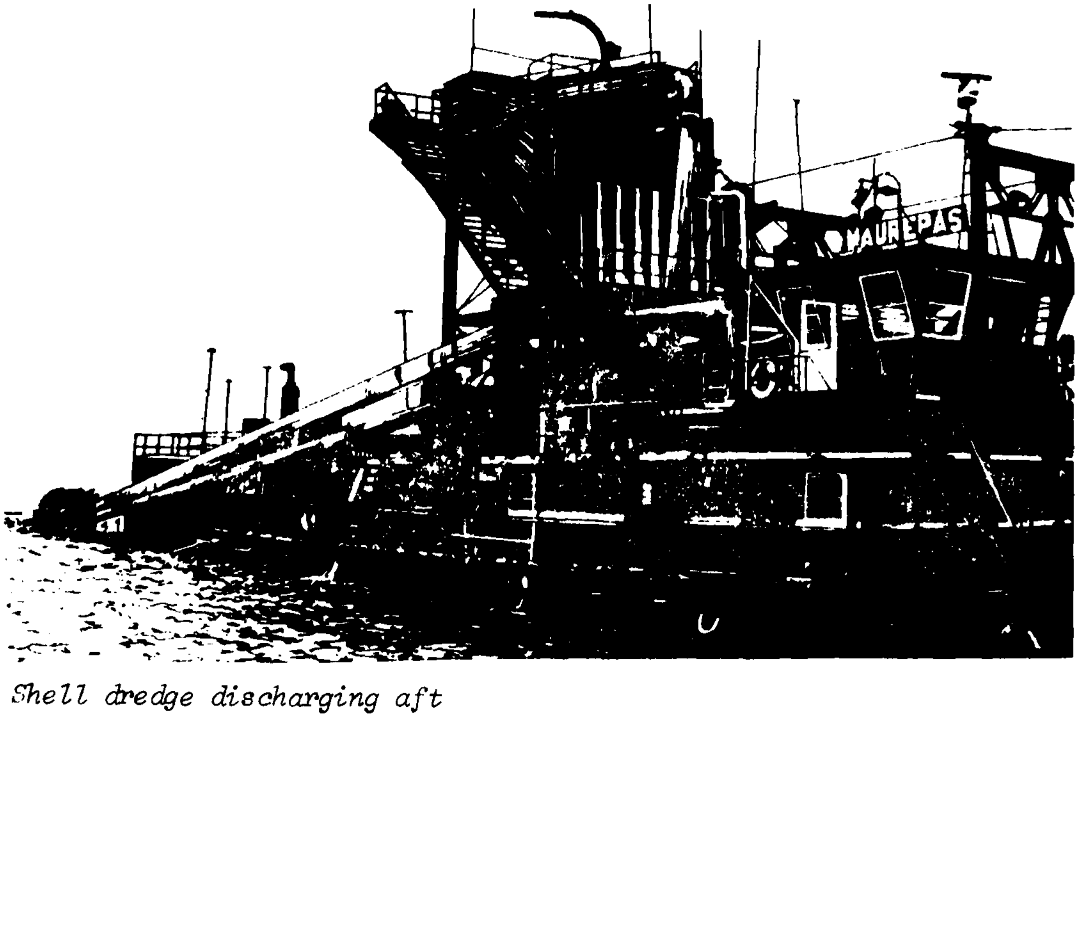
SUMMARY

Of the four Spartina patens marshes studied, the Walker Canal site was most productive. Net annual primary production was 2000-2500 g/m^2 higher in the Walker Canal site than in the Goose Point, Irish Bayou, and New Orleans East marshes. Higher productivity in this area may be caused by the influx of nutrient enriched upland runoff water (Cramer 1978). Results of this study show the Walker Canal area to have significantly

higher concentrations of nitrate-nitrite nitrogen and orthophosphate phosphorous in its adjacent waters than the other three marsh areas studied ($P < .05$). The effects of impoundment were not reflected in the productivity of Spartina patens in the New Orleans East area. Production values in the impounded marsh were similar to those of the Goose Point and Irish Bayou marshes, both of which are open to tidal flushing from Lake Pontchartrain. However, the high levels of organic nitrogen and carbon observed in the New Orleans East area indicate that the impoundment probably prevents export of nutrients and detritus from the marsh to the Lake Pontchartrain estuary. The impounded marsh is therefore effectively cut off from the Lake Pontchartrain estuary as a nursery ground area for juvenile fishes and as a source of nutrient and detritus export, both of which are important in coastal fisheries productivity (de la Cruz 1973). Salinity within the impounded area is low (1 ppt or less), and it appears that a gradual shift from the original brackish wetland to a more characteristically fresh marsh is taking place. This is evidenced by the low average monthly biomass of live Spartina patens (810 g/m^2) in the area compared to the other marshes studied (1440 g/m^2 average) and by the presence of freshwater species such as Juncus spp., Phragmites communis, and Alternanthera philoxeroides within the impoundment. Annual production estimates in all areas were higher than those reported by Payonk (1975) and White et al. (1978) for Spartina patens in Louisiana, but in the same range as those reported by Hopkinson et al. (1978, 1979) (Table 4).

Results of the swamp productivity studies showed the St. Charles Parish cypress swamp site to be a healthy area with production values comparable to those of similar Louisiana swamp forests. The Blind River

swamp forest site, however, had production values much less than those reported for typical Louisiana swamp forests (Conner and Day 1976). Tree species characteristics at the site were more typical of a cut-over swamp than a true bottomland hardwood forest because of previous intensive logging in the area. Low productivity in the Blind River swamp area could be the result of perturbation from logging activities; heavy insect grazing; and the continually flooded, low water, flow conditions.



Shell dredge discharging aft

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APPENDIX 1

MARSH PRODUCTION EQUATIONS

I. Smalley (1958) Aboveground Vegetation Growth Equations

1) If there was both an increase in the standing crop of living *Spartina* and an increase in the standing crop of dead *Spartina*, then net production was the sum of the increases.

2) If both living and dead standing crop decreased, then production was zero. Since production is defined as synthesis of organic matter, it cannot be negative, and decreases must be accounted for in terms of consumption, sedimentation, or loss from the system.

3) If the standing crop of living *Spartina* increased and the standing crop of dead *Spartina* decreased, production was equal to the increase in the living *Spartina*. Any decrease in dead *Spartina* is assumed to be due to loss to the tidal waters, but an increase in living *Spartina* can only be due to net production.

4) If the amount of dead *Spartina* increased and the amount of living decreased, they were added algebraically; if the result was negative, production was zero; if the result was positive, the resulting figure was equal to production.

II. Instantaneous Rate of Disappearance of Dead Material (Wiegert and Evans 1964):

$$r = \frac{\ln \left(W_o / W_1 \right)}{t_1 - t_o}$$

W_o is weight of dead material at start (t_o)

W_1 is weight of dead material at time t_1.

($t_1 - t_o$ is in days

r = disappearance rate in g:g:day

III. Growth of Aboveground Vegetation (Wiegert and Evans 1964):

t_i = time interval in days

a_i-1 = standing crop dead material at start

a_i = standing crop dead material at end

b_i-1 = standing crop green material at start

b_i = standing crop green material at end

r_i = instantaneous daily rate of disappearance of dead material during interval

1) Amount of dead material disappearing during an interval (X_i):

$$X_i = \frac{(a_i = a_{i-1})}{2 \cdot r_i t_i}$$

2) Change in green standing crop (Δb_i):

$$\Delta b_i = b_i - b_{i-1}$$

3) Change in dead standing crop (Δa_i):

$$\Delta a_i = a_i - a_i - 1$$

4) Mortality of green material (d_i):

$$d_i = X_i + \Delta a_i$$

5) Growth during interval (Y_i):

$$Y_i = \Delta b_i + d_i$$

APPENDIX 2

SWAMP PRODUCTION EQUATIONS

1. Regression Equations for Baldcypress Production (Schlesinger 1976):

Aboveground Production in grams:

$$\text{Log } Y = 1.6145 + 1.551 \text{ Log } X \qquad R^2 = .95$$

$$E = 1.29$$

Aboveground Dry Weight in kilograms:

$$\text{Log } Y = -.918 + 2.401 \text{ Log } X \qquad R^2 = .99$$

$$E = 1.161$$

Bole Dry Weight in kilograms:

$$\text{Log } Y = .9900 + 2.426 \text{ Log } X \qquad R^2 = .99$$

$$E = 1.161$$

Bole Wood Dry Weight in kilograms:

$$\text{Log } Y = -1.084 + 2.463 \text{ Log } X \qquad R^2 = .99$$

$$E = 1.20$$

Bole Wood Production in grams:

$$\text{Log } Y = 1.160 + 1.596 \text{ Log } X \qquad R^2 = .88$$

$$E = 1.54$$

Branch Wood and Bark in kilograms:

$$\text{Log } Y = -2.16 + 2.17 \text{ Log } X \qquad R^2 = .94$$

$$E = 1.50$$

Needles and Current Twigs in kilograms:

$$\text{Log } Y = -1.84 + 1.57 \text{ Log } X \qquad R^2 = .94$$

$$E = 1.34$$

Branch Production Wood and Bark in grams:

$$\text{Log } Y = -2.30 + 1.50 \text{ Log } X \qquad R^2 = .94$$

$$E = 1.325$$

For each regression:

X = diameter above the basal swell in cm.

Y = predicted component weight in g or kg as indicated.

E = an estimate of error.

R^2 = percent variance accounted for by the regression.

II. Regression Equations for Production of Hardwood Trees (Monk et al. 1970):

1) Stem production -

$$LOGY = 0.0294 + 2.3154 \log x$$

2) Leaf production -

$$LOGY = 0.9629 + 2.1861 \log x$$

3) Bole and large stem production -

$$LOGY = 1.9248 + 2.5546 \log x$$

4) Tree production -

$$LOGY = 1.9757 + 2.5371 \log x$$

For each regression:

Y = grams dry weight of either current year's stem, leaves, bole and large branches, or trees.

X = diameter at breast height in cm.

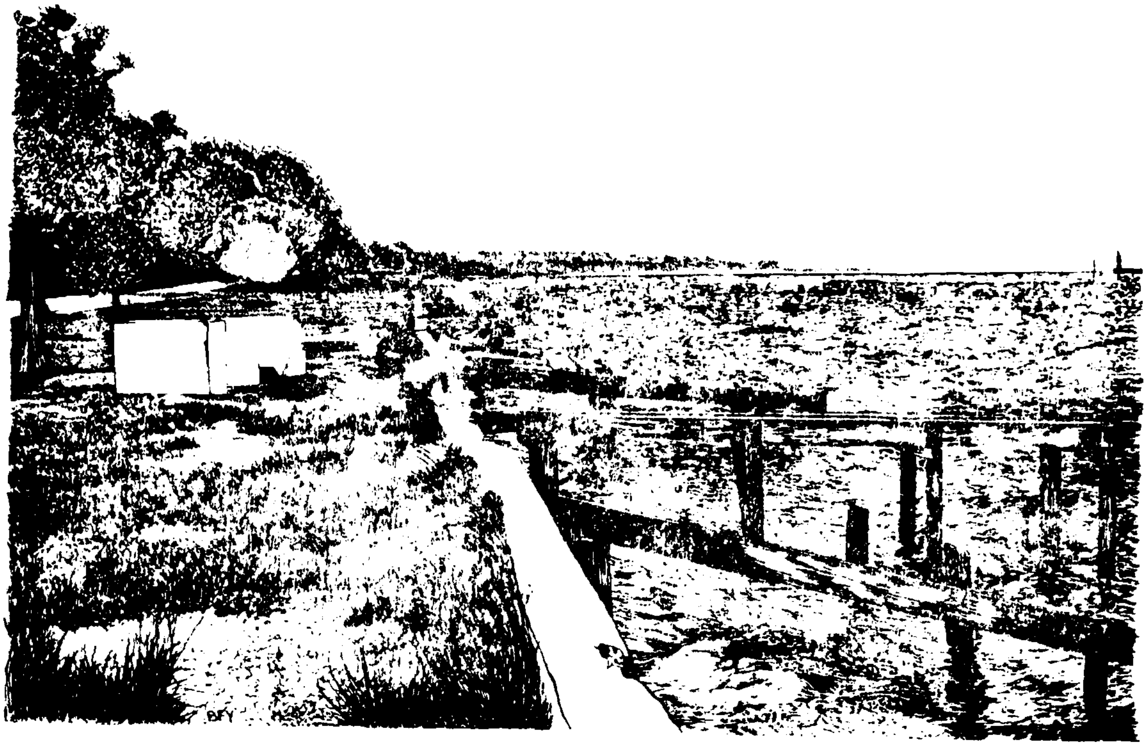
III. Swamp Transect Evaluation Equations (Mueller-Dombois and Ellenberg 1974):

1) $$\text{Relative density} = \frac{\text{number of individuals of species}}{\text{total number of individuals}} \times 100$$

2) $$\text{Relative dominance} = \frac{\text{dominance of a species}}{\text{dominance of all species}} \times 100$$

3) $$\text{Relative frequency} = \frac{\text{frequency of a species}}{\text{sum frequency of all species}} \times 100$$

4) Importance value (IV) = Relative density + relative dominance + relative frequency



Shc reline bulkhead near Mandeville, Louisiana

Chapter 10

CHANGES IN THE SUBMERGED MACROPHHYTES OF LAKE PONTCHARTRAIN (LOUISIANA): 1954-1973

by

R. Eugene Turner
Rezneat M. Darnell
Judith R. Bond

ABSTRACT

The shoreline distribution of submerged macrophytes in Lake Pontchartrain in 1954 is compared to that of 1973. There has been an apparent decline in the abundance and distributed of *Ruppia maritima* and *Vallisneria americana* but an increased distribution of *Potamogeton perfoliatus* and *Najas guadalupensis*. The specific factors causing the decline cannot be clearly identified, although increased salinity and urban expansion are implicated.

INTRODUCTION

An estimated 27% of United States' estuaries remain in a relatively natural condition (National Estuary Survey 1970). Clearcut documentation of the changes is rare, however, because of the scarcity of adequate surveys prior to potentially destructive influences.

During 1953-1955 an extensive ecological survey was carried out on Lake Pontchartrain, Louisiana, a large (2.4×10^5 ha), shallow (average depth 4m), estuarine lake (1-15 $^\circ/_{\circ\circ}$). The primary objective of the survey was an analysis of the ecology of the open waters of the lake (e.g., Suttkus et al. 1954, Darnell 1958, 1961, and 1964). However, attention was also given to the ecology of the littoral zone, and most

of this information has not previously been published. Of special interest here is information obtained on the distribution of submerged beds of rooted vegetation, which we compare to that of Montz's (1978) similar 1973 survey made during the opening of the Bonnet Carre Floodway.

MATERIALS AND METHODS

Data were derived from intensive surveys in the vicinity of the regular shore seining stations as well as from a special trip around the periphery of the lake, from 0-3 m depth, during the summer of 1954 for the purpose of mapping the distribution of the vegetation beds. This survey was conducted by towing a weed sampler (Fig. 1) behind the shallow draft vessel. This equipment was retrieved every few minutes to determine whether a bed had been encountered. When the sampler captured vegetation, the area was examined by wading (where possible) and by hand collecting to determine the extent and species composition of the vegetation. All plant identifications were made by Joseph Ewan of the Biology Department, Tulane University. The 1954 survey was relatively complete for the periphery of the lake, except for the western shore from Ruddock to the Tangipahoa River, and for the southeastern shore from South Point to The Rigolets (Fig. 2). We mapped the shoreline presence of the plants and compared it to Montz's (1978) maps, which were also based on an extensive summer survey.

A five-year running salinity average for the period 1954-1973 was obtained from the records maintained by the U.S. Army Corps of Engineers (COE) for a station at Little Woods, La., on the southeast lakeshore. The average was compared to the stream discharge of a representative tributary, the Tangipahoa River at Robert, La., for the same five-year period.

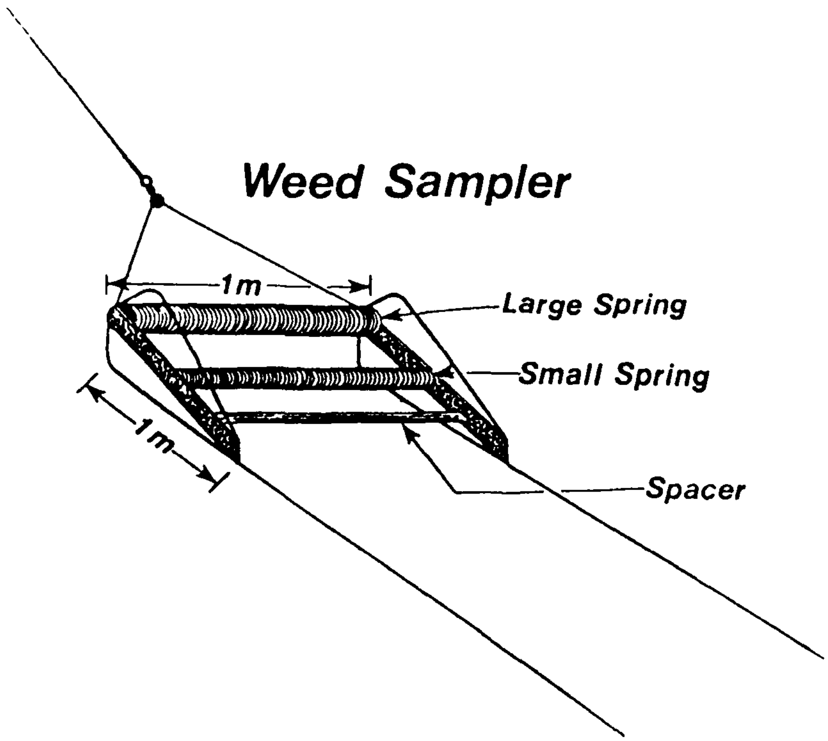


Figure 1. The sampling gear used to collect submerged macrophytes in 1954. Two springs, of 12.5 cm and 6.3 cm spacing, are mounted on a sled that is towed by a small boat.

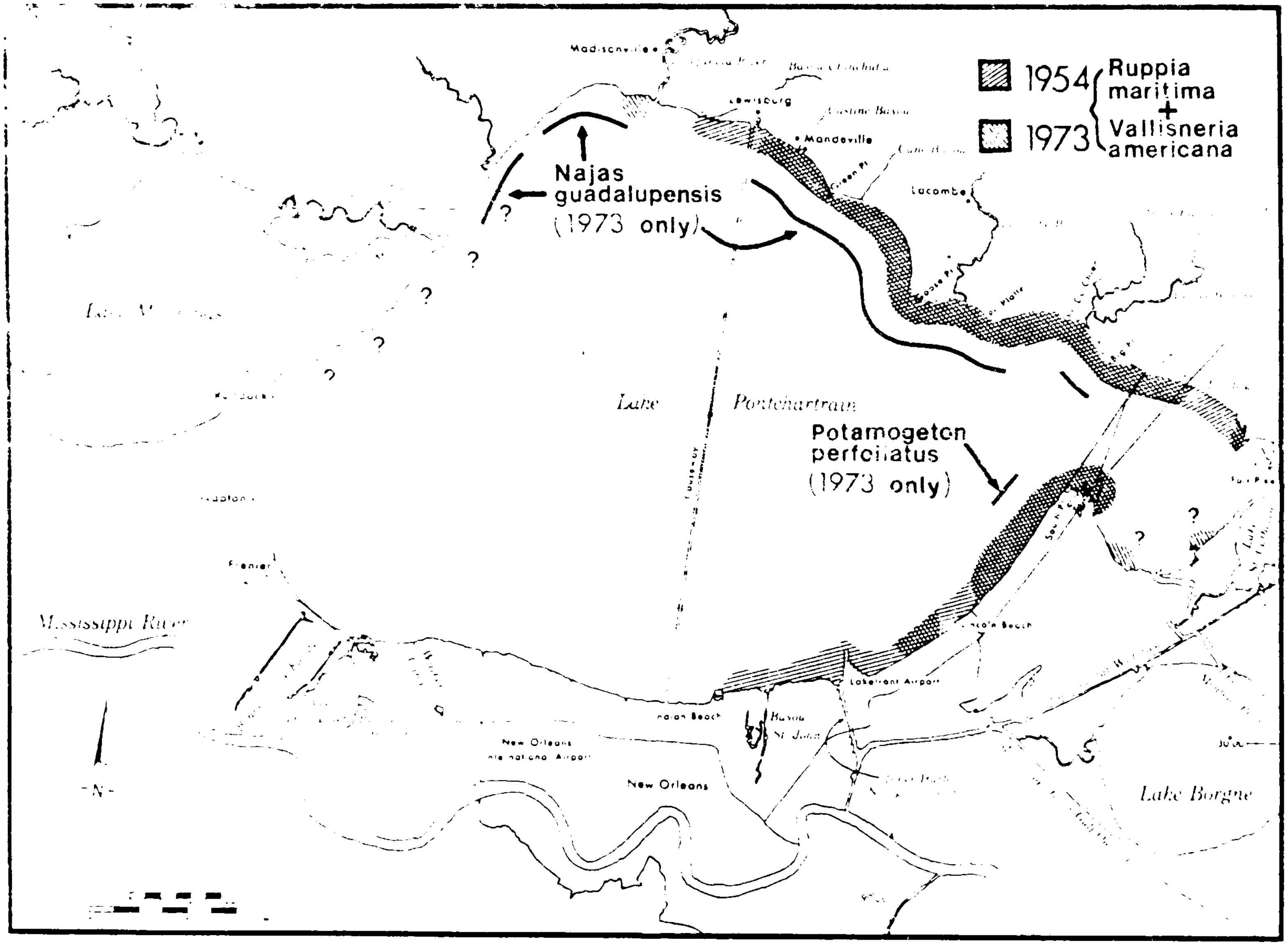


Figure 2. The distribution of grassbeds along the shoreline of Lake Pontchartrain, LA, in 1954 as compared to 1973. The question marks (??) represent areas that were not sampled in 1953-1954. The width of the shaded area is arbitrary; total area is not shown.

The land use maps of the U.S. Geological Survey (USGS) were examined to compare changes from 1954 to 1975 in the immediate vicinity of the lake.

RESULTS

The only submerged grasses found in the lake in 1954 were *Ruppia maritima* and *Vallisneria americana*. There was an apparent decline in the abundance of these two species from 1954 to 1973 (Fig. 2). Much of the loss occurred in the vicinity of the New Orleans beachfront and near the entrance to the estuary. Small patches of these macrophytes occurred in 1973 near the Tchefuncte River where there had been none before. Although it is not possible to precisely compare our findings with Montz's because of the subjective estimations for occurrence of the plants, it is worth noting that he observed the "infrequent" occurrence of plants along the southern shore where we observed them to be "abundant" in 1954. The net result is an apparent decrease of these two species along the shoreline between 1954 and 1973, which amounts to a 25-33% reduction. Other differences are that Montz (1978) found *Najas guadalupensis* where none were located in 1954. This may be a real change in distribution. Montz described *Najas* sp. as "infrequent" in water less than 30 cm deep, so we may have missed them in the 1954 survey. *Potamogeton perfoliatus* was found to be abundant in 1973 but none were found in 1954 in an area that we believe was surveyed adequately then. However, *Potamogeton perfoliatus* was collected in 1943 by C. A. Brown in the lake near Mandeville, La. (Haynes 1968).

The salinity of the lake, as represented by the changing salinity at Little Woods, was similar or lower in 1954 than in 1973 (Fig. 3). The annual variations in salinity reflect annual variations in streamflow.

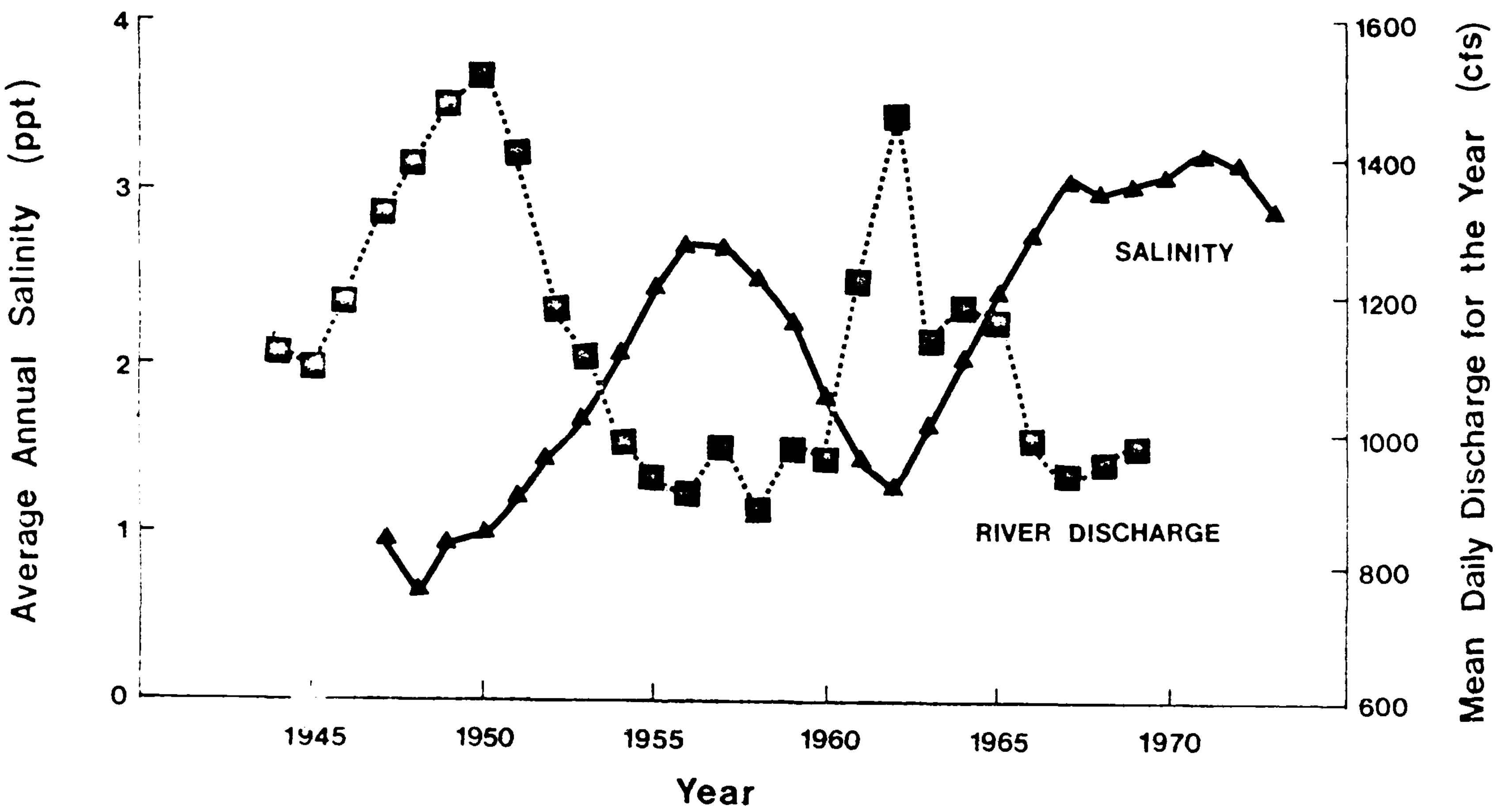


Figure 3. The lake salinity at Little Woods, LA, and the river discharge of the Tangipahoa River at Robert, LA (from COE data).

The land use patterns in the immediate vicinity of the lake have changed tremendously with the growth of New Orleans (Fig. 4). Thousands of acres of wetlands have been drained, filled, or leveed for agriculture or urban expansion; numerous channels were built to drain water pumped from the city up to sea level and into the lake. At one time there were vast areas of grassbeds behind the present New Orleans seawall on the lakefront, especially in the recently urbanized area (P. Viosca, pers. comm.). Further urban expansion has occurred on the north shore near Mandeville, Madisonville, and Slidell. We estimate that urban areas in 1972 compared to 1954 are three times and eight times greater on the south and north shore, respectively. There were few changes in the types and quantities of land use within the whole watershed, except for the growth of Baton Rouge to the northwest. The major decline in vegetation is where urban growth has occurred.

DISCUSSION

Indications are that from 1954 to 1973, the abundance and distribution of Ruppia and Vallisneria in Lake Pontchartrain have declined whereas other rooted aquatics have expanded their range in certain areas. Perret et al. (1971) mentioned Ruppia sp. and Vallisneria sp. as the only "abundant" species in Lake Pontchartrain during their 1968-1970 survey. Montz (1978) noted that their earlier survey indicated ten times more acreage of rooted aquatics present than he found.

We cannot clearly identify the specific causal agent(s) of these changes. Some adjustments to rising salinities may have occurred. For example, on the south shore a saltwater source, the Mississippi River Gulf Outlet, was connected to the Inner Harbor Navigation Canal between surveys in the same vicinity where the grassbeds are no longer evident

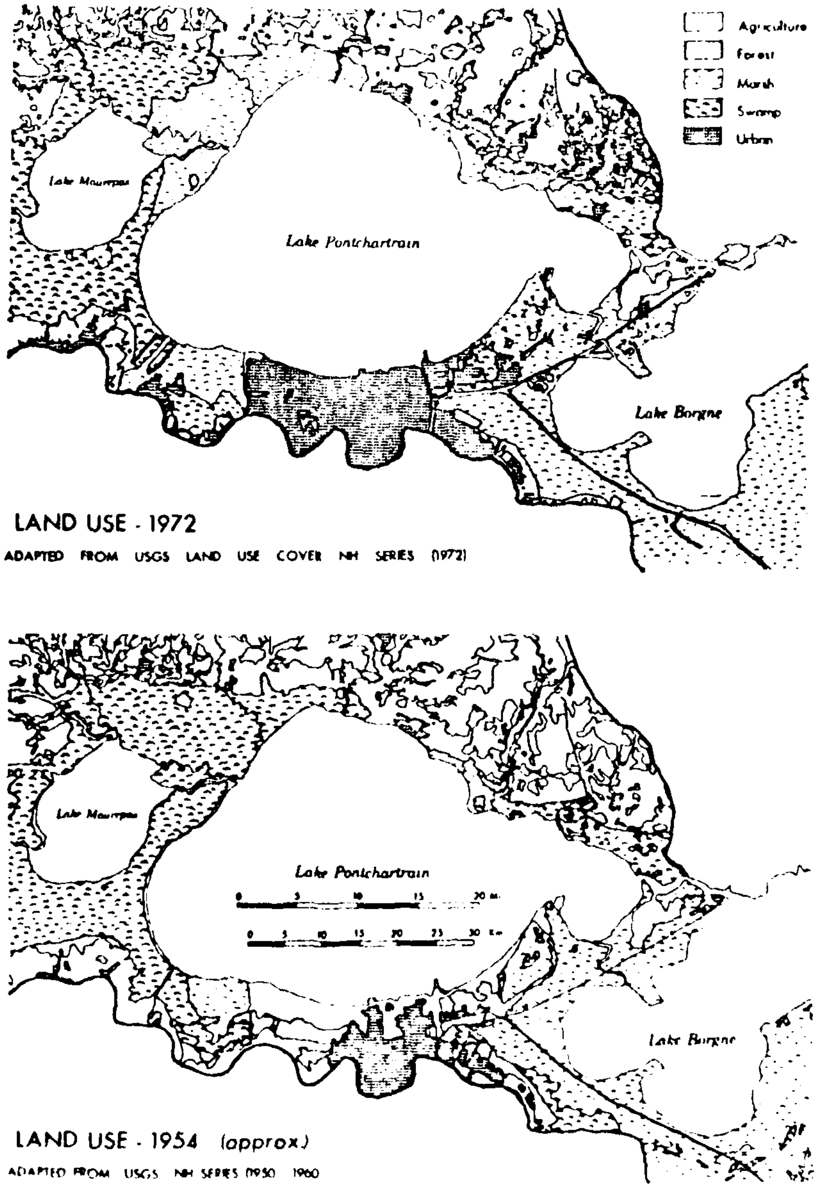


Figure 4. Land use in the vicinity of Lake Pontchartrain, LA, in 1954 (lower figure) and in 1972 (upper figure).

(cf. Chapter 4). There may have been a contraction or expansion of the grassbeds on the eastern edge near the other saltwater source, The Rigolets, but this could not be determined because the area was not surveyed in 1954. It was surveyed along the eastern end of the northern shoreline where there was a decrease. There was also a loss at the western edge of the northern shore boundary, away from all saltwater sources. All of these same areas of loss are also adjacent to areas of recent urban expansion. Bayley et al. (1978) postulated that the recent changes in submerged macrophyte communities of Chesapeake Bay were related to eutrophication, salinization, and increases in turbidity that were caused by urbanization and agricultural activities. However, the area of agricultural lands in the Lake Pontchartrain watershed has decreased from 1954 to 1972. Lake nutrient concentrations near New Orleans (Dow and Turner, Chapter 7) are much higher nearshore than a few kilometers offshore primarily because of the canals that empty sewage and street runoff from the city (cf. Stoessell, Chapter 6). Herbicides, pesticides and chlorine may also be detrimental to the growth of submerged macrophytes (Stevenson and Confer 1978, Mann 1973).

There are really no comprehensive studies of these Louisiana ecosystems comparable to those on *Zostera* sp. (McRoy 1966) or *Thalassia* sp. (Zieman 1968). In general, submerged macrophyte communities serve as a habitat and as a food source for many organisms. Additionally, macrophyte communities act as geological agents (Schubel 1973).

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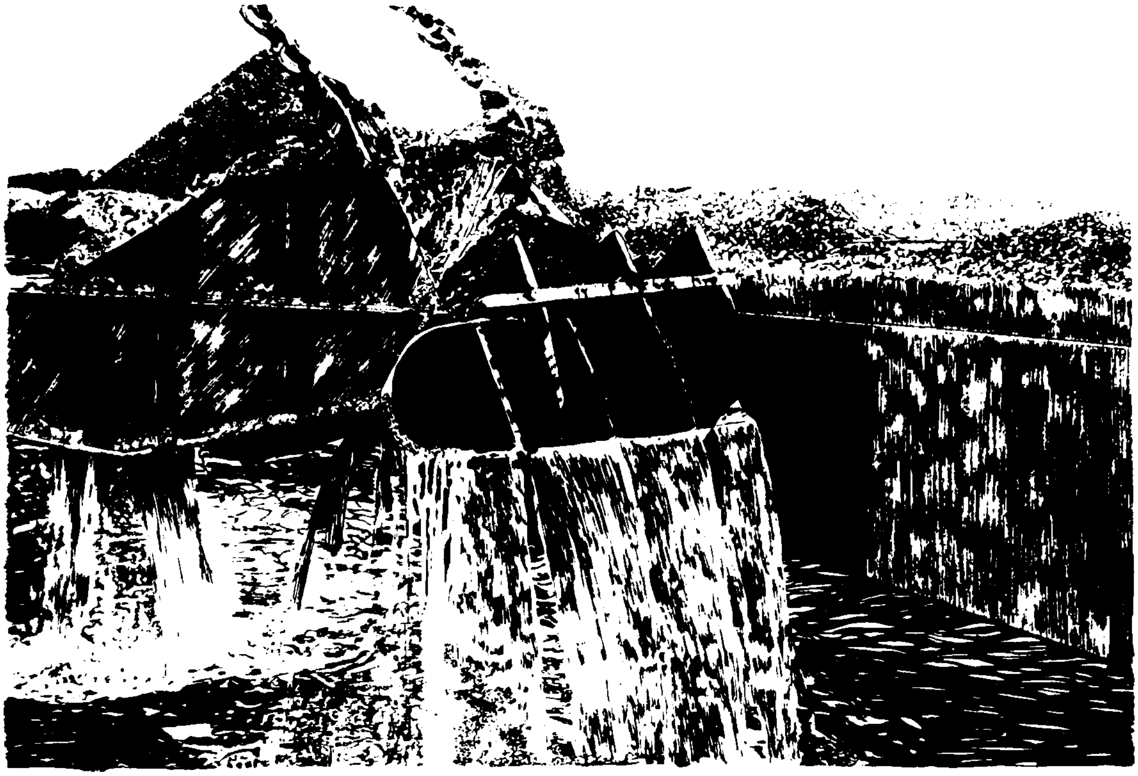

View of cutting head of dredge

Chapter 11

MACROBENTHIC SURVEY OF LAKE PONTCHARTRAIN, LOUISIANA, 1978

by

Leonard M. Bahr Jr., Jean Pantell Sikora, and Walter B. Sikora

ABSTRACT

A recent survey of macrobenthos and sediments in Lake Pontchartrain, Louisiana, was conducted to select ten representative monthly sampling stations and three seasonal (quarterly) stations for a benthic characterization study. Results of the survey indicate that the open lake bottom is dominated by silty clay sediments (47.6%) and that benthic macrofauna are relatively sparse throughout the open lake, with an average density of 3116 $\pm$ 447 organisms/m^2. Only 24 species of macrofauna were identified in a total of 104 samples, each 0.09 m^2 in area.

The estuary has undergone such cultural impacts as impoundment of wetlands; urbanization; industrial, agricultural, and petrochemical pollution; excess sediment loading from the Mississippi River; and shell dredging. Nutrient levels and turbidity are high; primary production is only moderate; toxins are present; and demersal nekton in the open lake are relatively scarce.

Statistical analyses of the initial survey data indicate that macrofaunal distribution is only poorly explained by salinity, grain size, organic matter, urban influence, or dredging effects; although the latter explains 14% of the variability in total faunal distribution.

INTRODUCTION

Lake Pontchartrain is a south-temperate oligohaline estuary that is located in the geologically active Mississippi River deltaic plain of southeastern Louisiana. The lake formed about 4500 years B.P. (before present) when a portion of the Cocodrie deltaic system partially cut it off from an embayment of the Gulf of Mexico (Saucier 1963). The present dimensions of the lake (Fig. 1) are as follows: 53.1 km, mean dia.; 1631 km^2, area (U.S. Army Corps of Engineers [COE] 1962). These dimensions probably reflect the long-term physiographic effects of bottom and shoreline erosion, sedimentation, downwarping, and subsidence. The latter processes have affected the lake at different rates in different areas. Thus, the exceptionally flat bathymetric profile of the present lake bottom probably indicates a continual redistribution of bottom sediments (Fig. 2).

It has been postulated that the mean depth of Lake Pontchartrain is maintained at equilibrium as a result of erosion and export of incoming sediments by wind-driven currents that are proportional to the average fetch (Price 1947). If valid, this hypothesis implies a constant flux of sediments through the upper "biogenic" lake bottom either by the flushing of new (riverine) sediments from the lake or by their burial and gradual subsidence. At any rate, despite continual sedimentation, the lake has not become more shallow in recent times and may even be deepening, perhaps as a result of cultural effects. The mean depth of the lake was reported 40 years ago as 3.5 m (Steinmeyer 1939), whereas the present depth is about 3.7 m mean depth.

Recent cultural influences on Lake Pontchartrain include: (1) major losses to and/or impoundment of bordering wetland areas; (2) urbanization,

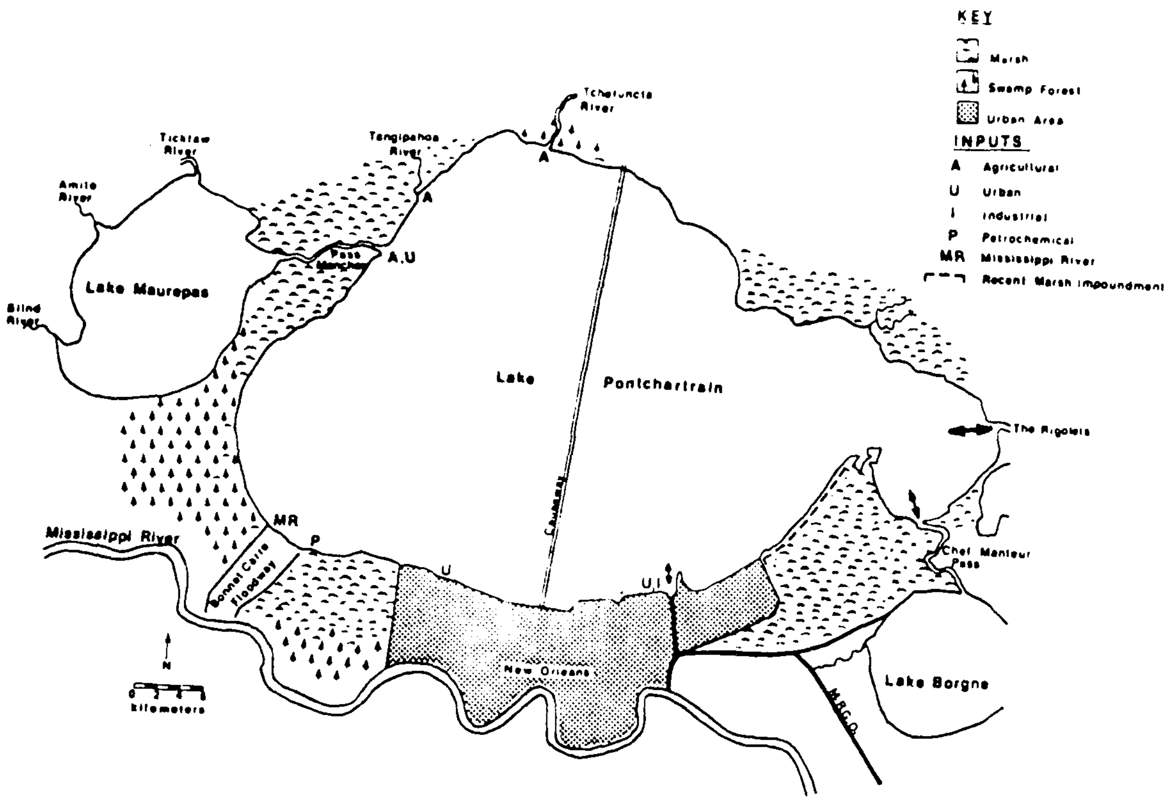

Figure 1. Lake Pontchartrain, LA, showing the location of some of the cultural impacts on the lake's ecosystem.

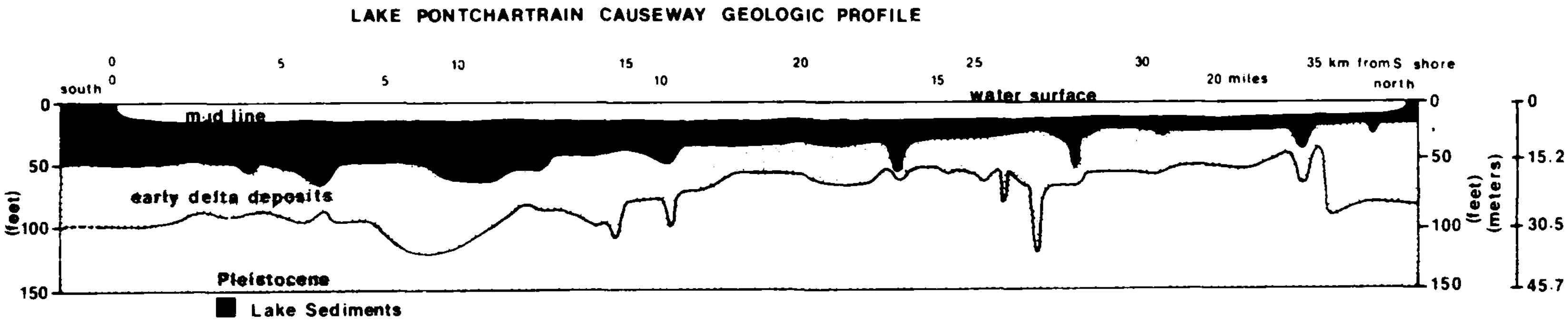

Figure 2. North-to-south horizontal profile of the bottom sediments of Lake Pontchartrain, LA, showing subsurface deposits.

both at the south shore at New Orleans and (increasingly) along the north shore; (3) nutrient inputs from urban and agricultural sources; (4) pollutants from petrochemical and agricultural sources; (5) extensive shell dredging in fossil shell deposits of *Rangia cuneata*; and (6) major aperiodic inputs of Mississippi River water and sediment as a flood control measure via the Bonnet Carre Floodway. The Bonnet Carre has been opened three times during the last decade.

The primary objective of this report is to summarize and to interpret the results of a survey of macrofauna and sediments in Lake Pontchartrain that was conducted from March to May 1978 as the preliminary phase of a benthic characterization study of the Lake Pontchartrain ecosystem. The primary purpose of the survey was to determine the heterogeneity of the benthic community throughout the lake to select a set of permanent monthly sampling stations that would be most representative of the entire benthic system. The monthly sampling stations were in turn to be used in an ongoing benthic characterization study funded by a contract from the U.S. Army Corps of Engineers (DACW 29-79-C-0099).

MATERIALS AND METHODS

I. Field and Laboratory

The lake was divided into a grid system of 86* quadrats (Fig. 3) identical in position to those used by Tarver and Dugas (1973), with each quadrat 23.2 km^2 except for those on the lake edge. Benthic samples (0.09m^2 in area) were taken with a J. and O. box core (Jonasson and Olausson 1966). One box core was taken in each quadrat, with a replicate

*Only 85 quadrats were actually sampled.

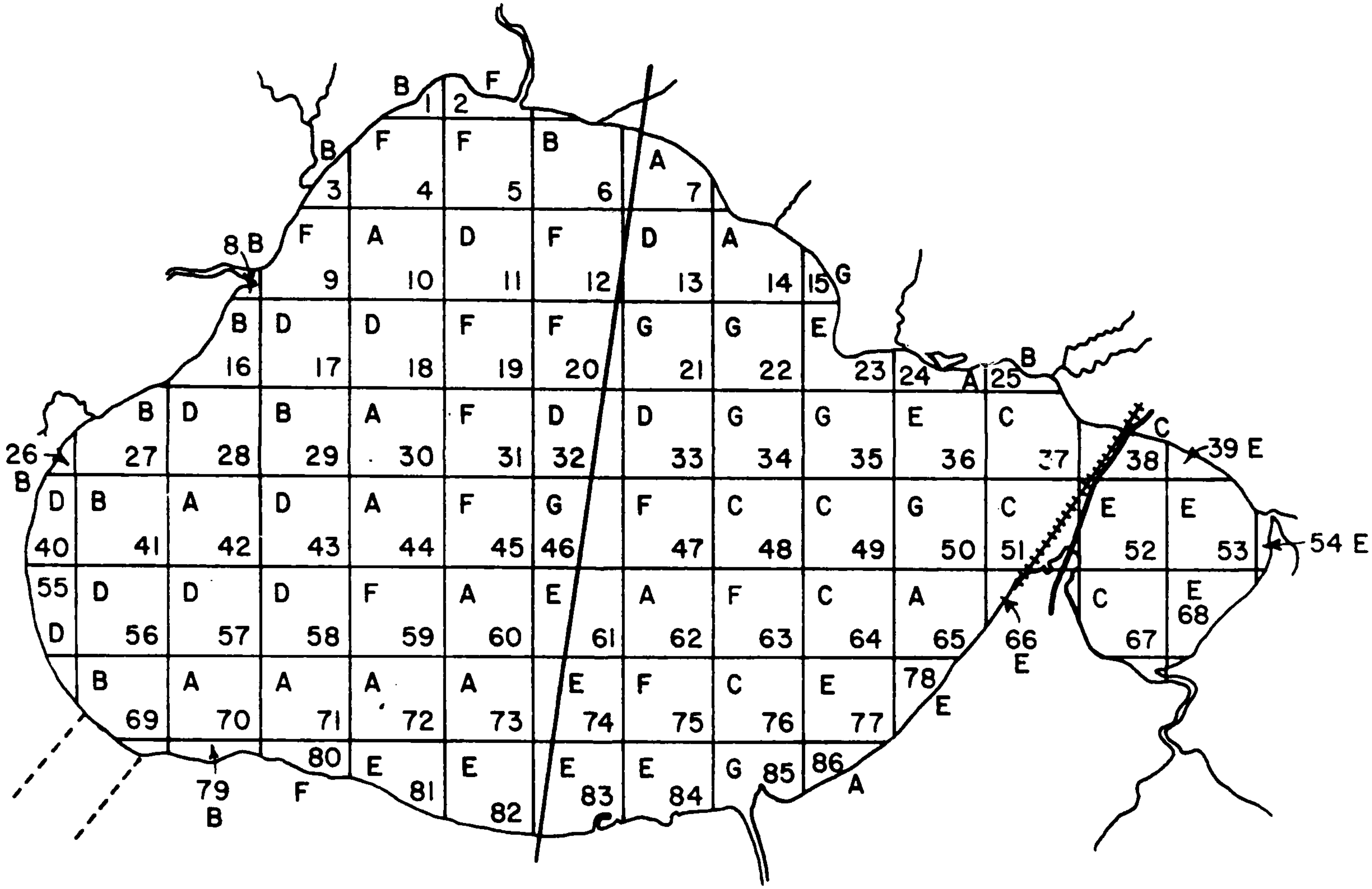

Figure 3. Initial survey quadrats in Lake Pontchartrain, LA, 1978, with clusters identified by letters (cf. cluster analysis, Figure 12).

core taken at every fourth quadrat. Overlying water was siphoned from the box core through a 0.5 mm screen, after which the contents were emptied into a sieving box and washed through 1.2 cm and 0.3 cm screens to remove coarse shell. Material from the sieving box flowed onto a 0.5 mm nylon screen where final field washing and sieving were accomplished. Animals were sorted from the coarse shell fraction onboard ship; added to the contents of the 0.5 mm screens; preserved with 10% buffered formalin; and brought back to the laboratory for final sorting and enumeration at the species level.

Separate cores of approximately 38.5 cm^2 were taken at each quadrat with a ball check-valve pole corer for sediment analysis. A standard hydrometer method of particle size analysis was used (Day 1956; McBride 1971). Bedding structure was examined in many samples using x radiographs of vertically sectioned cores.

Total organic carbon of the upper 2-3 cm was measured with a Laboratory Equipment Company (LECO) induction furnace Model 521-100 coupled to a semiautomatic gasometric carbon determinator.

II. Statistical Analysis

A computer program provided by Bloom et al. (1977) was used for the numerical classification of the data obtained from the initial survey to obtain more information on the number and types of communities in the study area. The amount of data obtained in large-scale benthic surveys is not easily analyzed by other techniques. Some examples of the earliest uses of these particular multivariate techniques are Lie and Kelley (1970), Stephenson and Lance (1970), Hughes and Thomas (1971), Field (1971), and Boesch (1973). Since these earlier studies, the use of

classification has become a standard technique for simplifying and extracting information from the very complex patterns evidenced by large collections of multispecies populations.

Simultaneous double standardization with no transformations of the data was used (Boesch 1973):

$$y_{ij} = \frac{x_{ij}}{(\sum_j x_{ij} \sum_i x_{ij})0.5}$$

where x_{ij} is the unstandardized value of the i-th species in the j-th collection. Use of this standardization eliminates problems that can occur when there are very large and very small collections, or when there are some species with very high numbers in one sample and very low numbers in others.

For the classificatory analysis, flexible sorting with the β set at -0.25 by convention (Boesch 1973) and with the Canberra metric coefficient in its dissimilarity form

$$D_{jk} = \frac{1}{n} \sum_i^h \frac{|x_{ij} - x_{ik}|}{(x_{ij} + x_{ik})}$$

with e = 0.01 was used.

These techniques presuppose a data matrix with species in one direction and collections at one time over a large area (spatial variation), or collections at one site over a time period (temporal variation) in the other. Because we were attempting to analyze the occurrence of specific clusters of sites over a large area and because sampling that large an area took a finite amount of time, it was necessary to include time as one of the variables in the step-wise multiple regression analyses

to ascertain the effects of time on the distribution of the species included in the cluster analysis. Actual sampling dates were converted to Julian dates for the analysis.

SAMPLING SITE SELECTION

I. Overall Area

Because we were constrained to a monthly sampling schedule at 10 stations in Lake Pontchartrain, we were faced with the selection of 10 locations that would give us maximal representation of the very large area involved. The initial survey (on which the site selection was based) was limited to the open lake, excluding the lakeshore because of the minimum depth required for our boat. In addition, we decided that a benthic characterization based on only 10 monthly sampling sites would be strongly biased by edge samples, which would be significantly different from open lake samples.

The selection of specific sites was necessarily based on information available to us prior to the onset of the monthly sampling program. This information was limited to the quantitative and qualitative parameters shown in Table 1. More detailed statistical analyses of the survey results were carried out after the sampling sites had been selected; therefore, these results are reported in a later section.

Below is a discussion of the specific technique by which we arrived at our sampling stations.

II. Physico-Chemical Factors

Figure 4 shows maximum salinity readings of bottom water at each of 12 stations during the period from 1972-1974. These data are from

Table 1. Preliminary Information Used to Determine Permanent Monthly Benthic Sampling Stations in Lake Pontchartrain, LA, in 1978

Detailed biological data

1) Current macrofaunal distribution by species or general taxa (>.05 mm)
2) Recent macrofaunal distribution (Tarver and Dugas 1973; Tarver and Savoie 1976; Dugas et al. 1973)
3) Previous macrofaunal distribution (Darnell, unpublished qualitative data, 1953-1954)
4) Preliminary data on demersal fish distribution and gut contents

Detailed physico-chemical data

1) Current grain size distribution in surface sediments (% sand, silt, and clay)
2) 1972-1974 grain size distribution (Tarver and Savoie 1976)
3) Present distribution of organic carbon in surface sediments
4) Two-year data on salinity, temperature, and turbidity of bottom water during 1972-74 (Tarver and Savoie 1976)

General information

1) Limited new data on water current regimes in different areas of the lake
2) Potential effects on biota of proximity to urban influence, riverine input, marine influence, shell dredging activity, shoreline, etc.
3) Cost in terms of labor and logistics of including alternate station sites

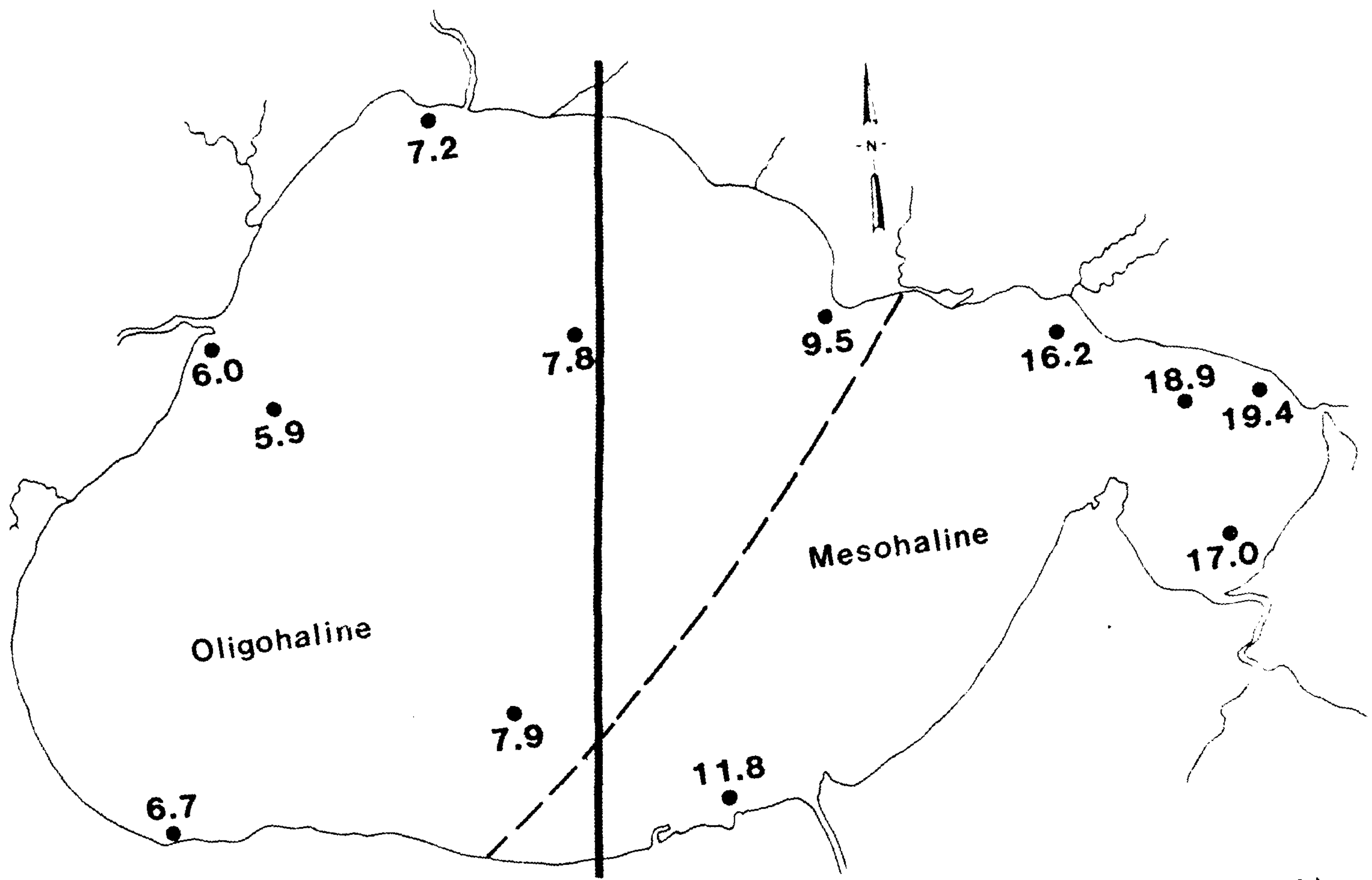

Figure 4. Maximum recorded salinity (°/₀₀) at twelve stations in Lake Pontchartrain, LA, during the period from 1972-74 from Tarver and Savoie (1976).

Tarver and Savoie (1976). The salinity regime of the lake is clearly divisible into two regions: a western low salinity zone and an eastern higher salinity zone. These two zones comprise approximately 60% and 40% of the lake area, respectively. Because salinity is of primary importance to estuarine organisms, we decided to apportion our 10 sites in like manner, with six sampling sites in the western region and four in the eastern.

Likewise, because benthic organisms are ordinarily strongly dependent on sediment type, we decided to apportion our 10 sites (in relative fashion) among areas of differing sediment types (grain size). Results from the sediment analyses revealed a high diversity of sediment types, as shown in Fig. 5. The proportion of each of the seven types was calculated as follows:

Sand	5.0%	
Silty-Sand	12.2%	21.8%
Clayey-Sand	4.6%	
Sandy-Silt	9.3%	
Clayey-Silt	19.5%	28.8%
Sandy-Clay	1.8%	
Silty-Clay	47.6%	49.4%

Relative areas of lake bottom characterized by these proportions of sediment type suggest a second partitioning--i.e., five stations in clay, three in silt, and two in sandy substrates.

At this point we had determined to locate three of the "clayey" stations, two of the "silty" stations, and one of the "sandy" stations in the western (oligohaline) zone and two of the "clayey" stations and one each of the "silty" and "sandy" stations in the eastern (mesohaline) zone.

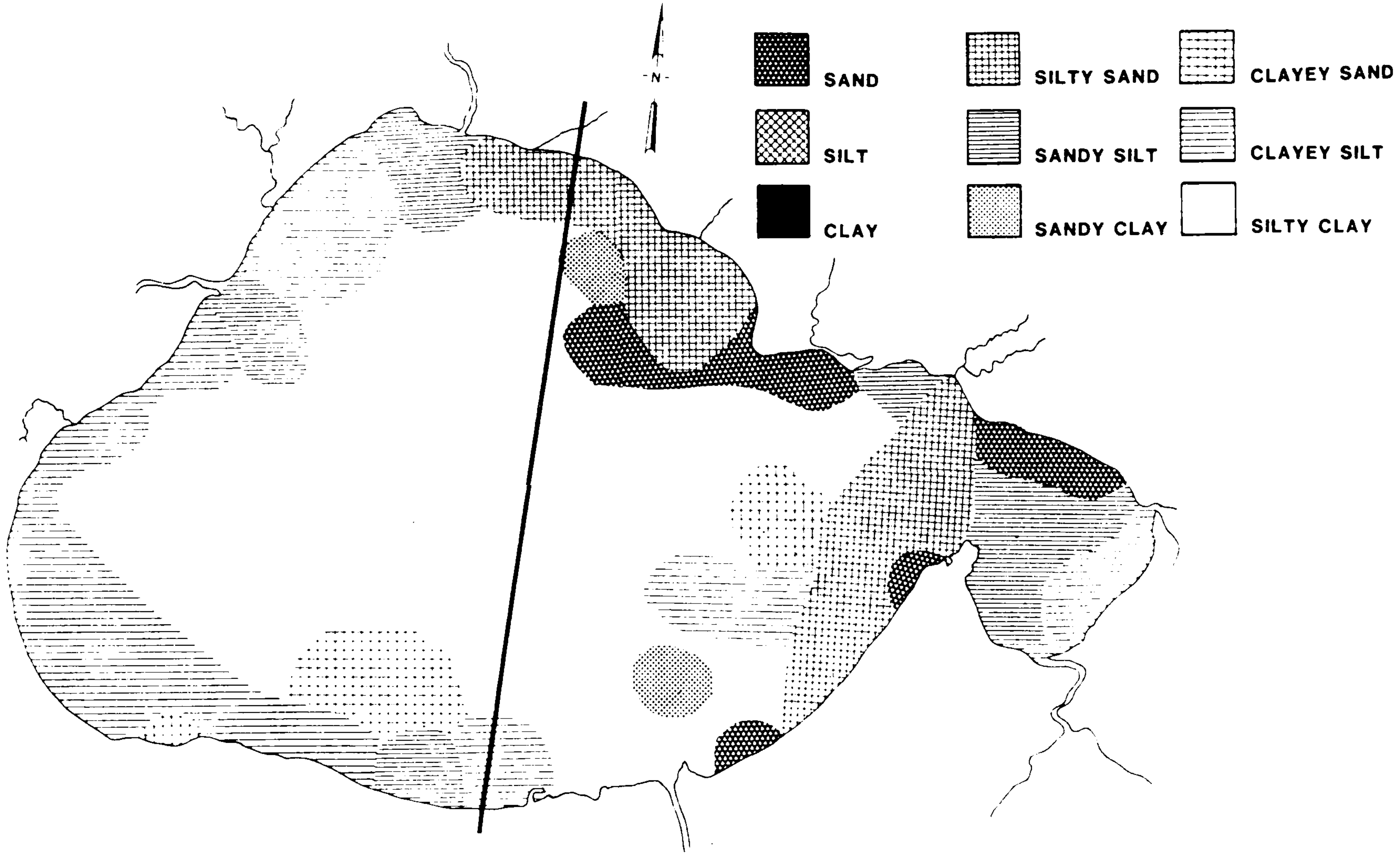

Figure 5. Distribution of sediment types in Lake Pontchartrain, LA, as determined during the present study.

The third variable considered was the distribution of organic carbon in surface sediments. This distribution is shown in Fig. 6. The organic carbon levels in Lake Pontchartrain are somewhat lower than in the sediments of higher energy estuaries such as in coastal South Carolina and Georgia. The mean value for the lake is 1.06% organic carbon by weight, with a standard deviation of 0.49. These numbers do not include two stations that had very high values: a sewage outfall in Jefferson Parish and a peat deposit at the southwestern edge of the lake.

In choosing stations, we considered the organic levels so that in each sediment type, we included as wide a range of organic carbon as possible. This allowed us to further narrow our site locations.

Data were collected on shell volume per sample, and variability in this parameter was considered to be related to dredging activities, at least in the center of the lake. Figure 7 shows the results of these data, indicating areas with few shells. We attempted to position our stations so as to include areas of both high and low shell density.

III. Distribution of Organisms

Figure 8 illustrates the distribution of all macrobenthic organisms counted in all samples, overlaying a map of sediment distribution. Total number of species (or taxa) found at each quadrat are shown in Figure 9.

The distributions of abundance of individuals of each major species or taxa were plotted separately to visually check for patterns [illegible] effects of physico-chemical and geographical factors. Each [illegible] plots is included in an appendix. Where alternate sampling [illegible]

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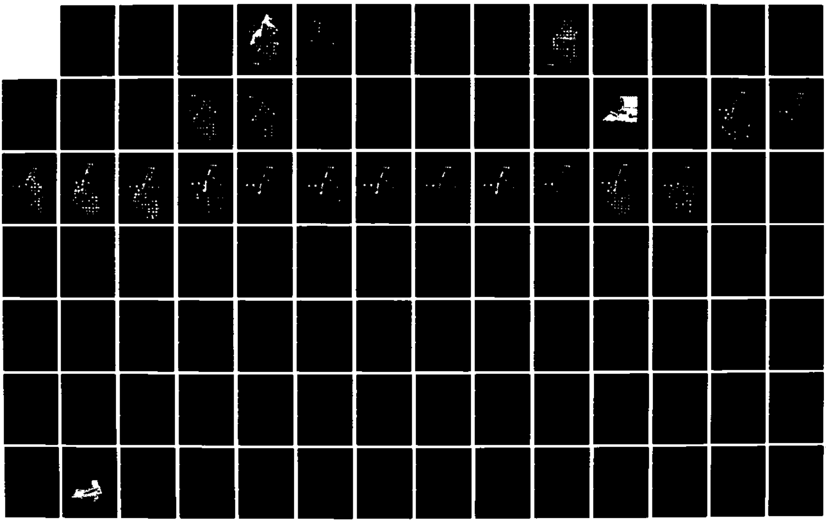

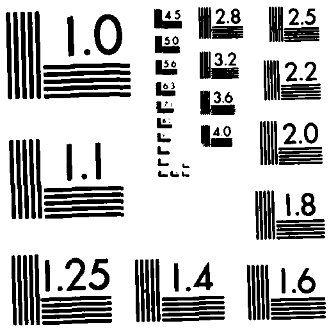

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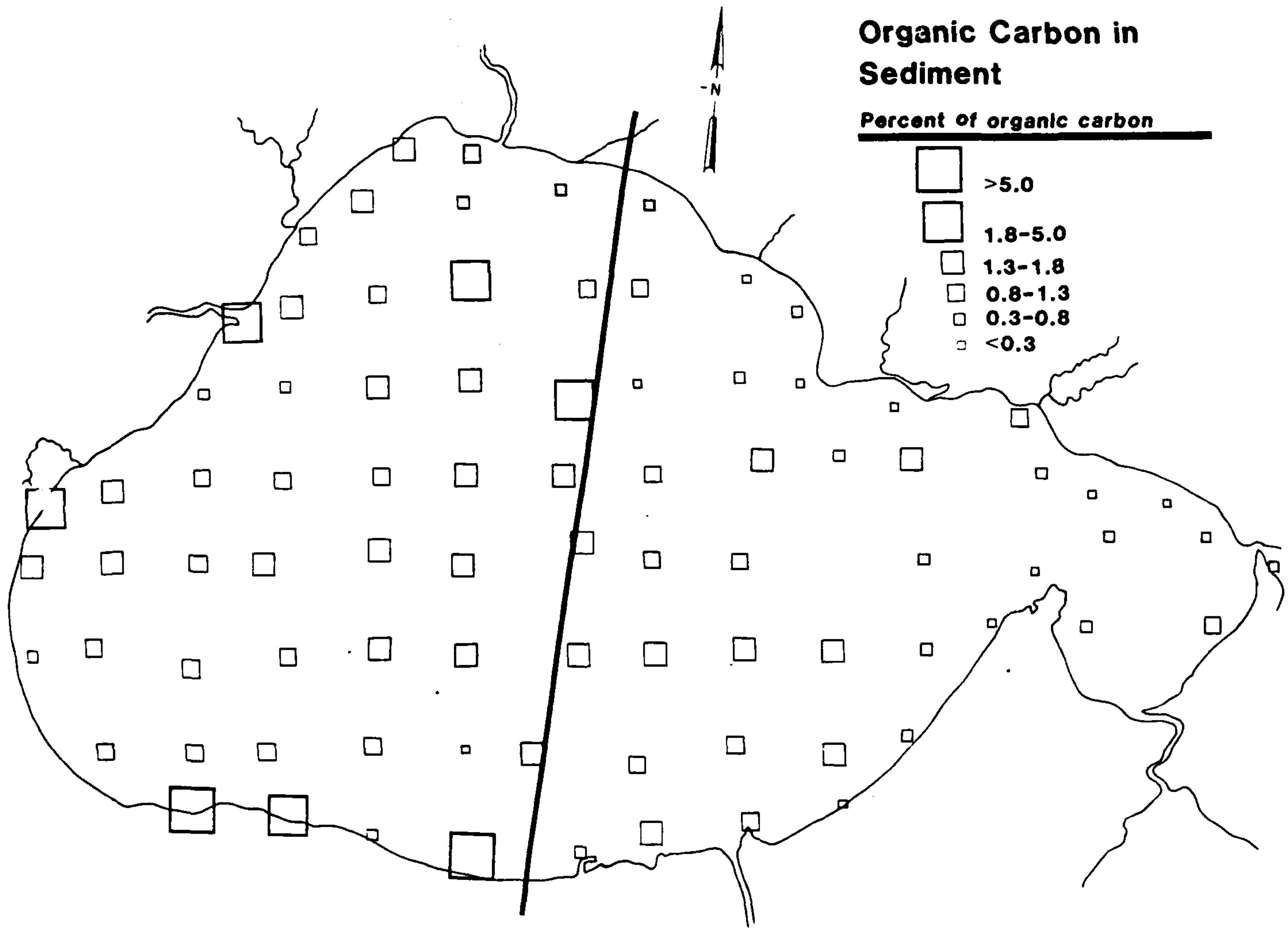

Figure 6. Distribution of organic carbon in surface sediments of Lake Pontchartrain, LA, as determined during the present study.

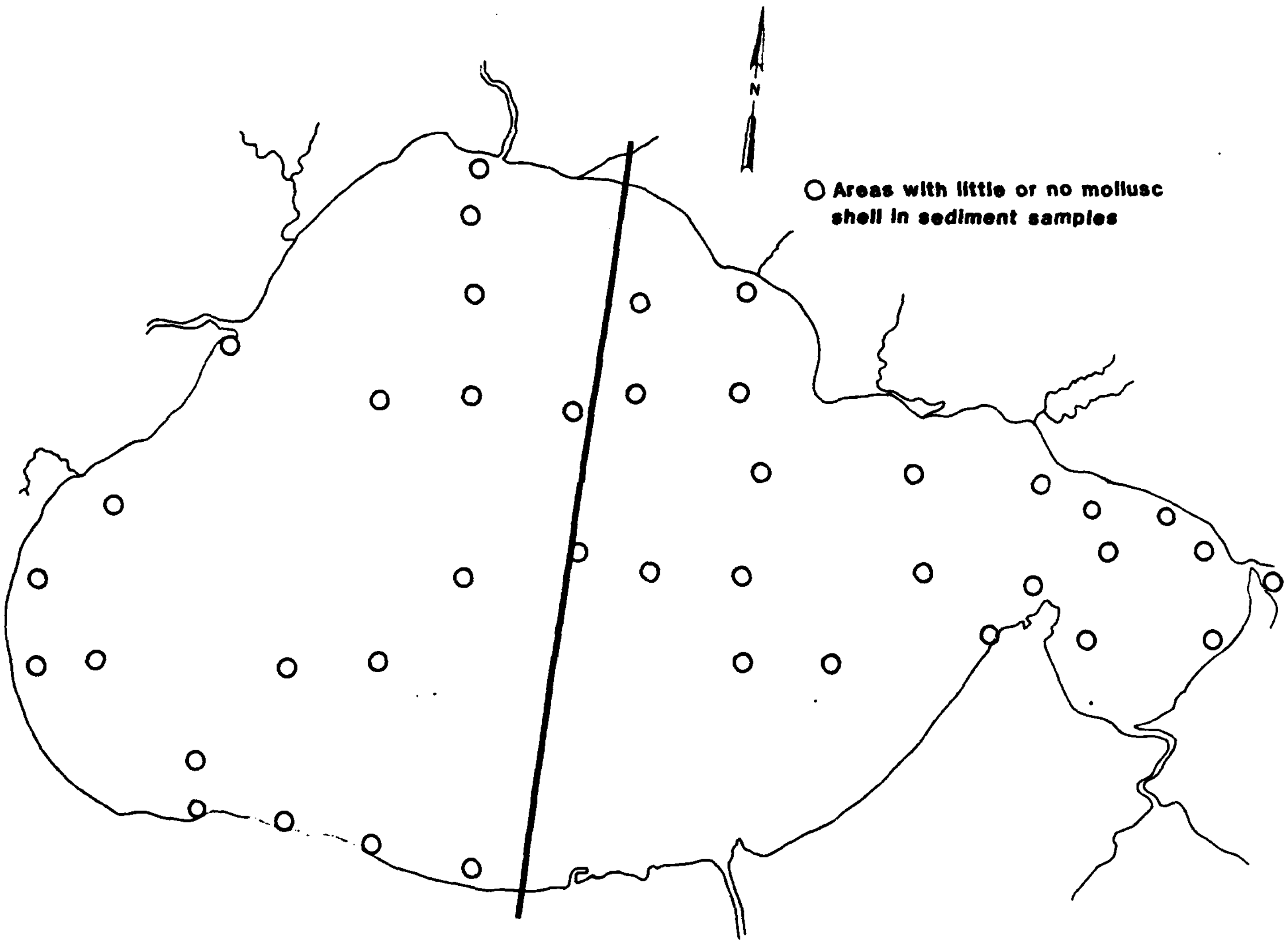

Figure 7. Location of survey stations of Lake Pontchartrain, LA, where little or no shell was found in surface sediments.

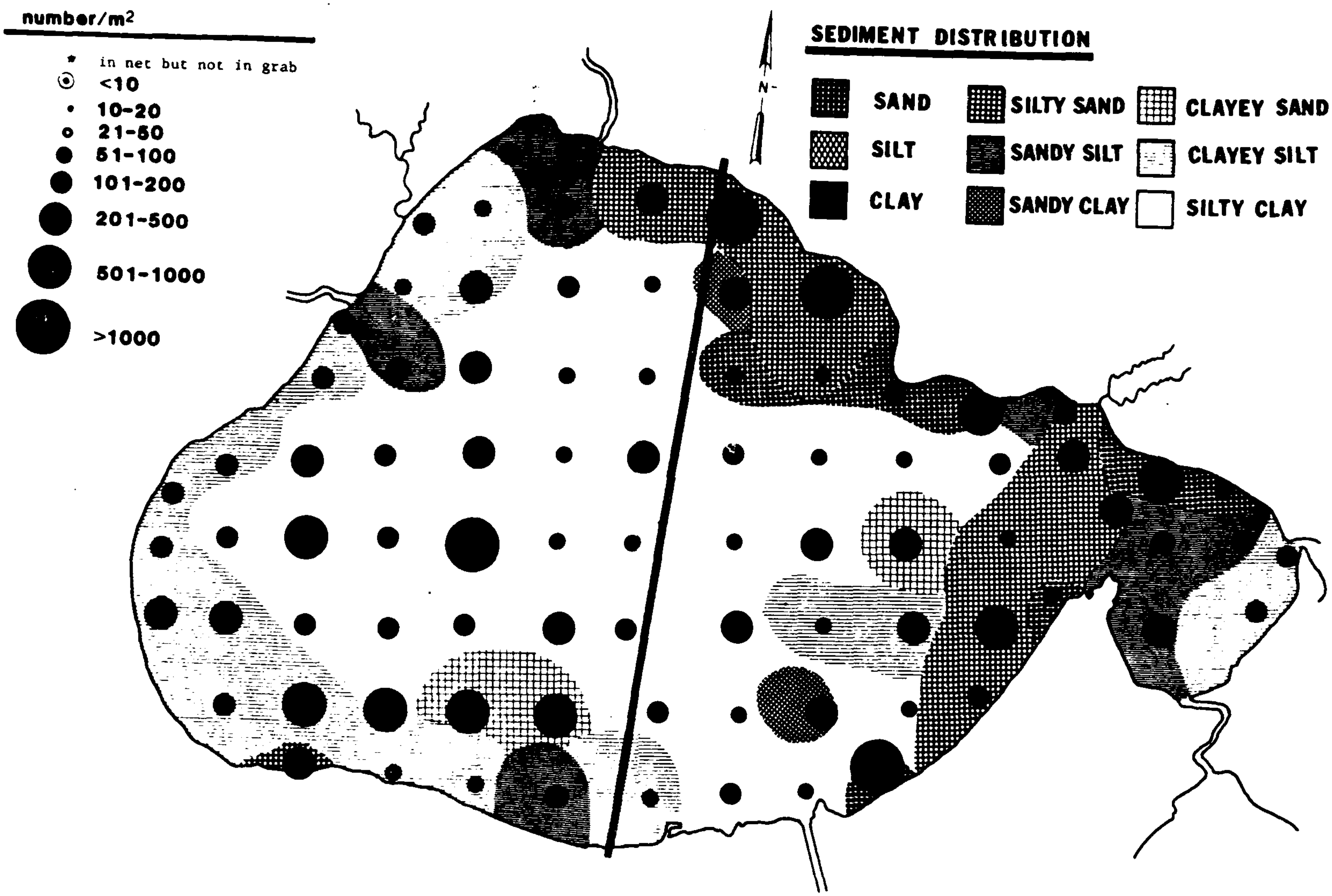

Figure 8. Distribution of total macrofaunal organisms in surface sediments of Lake Pontchartrain, LA, as determined during this study.

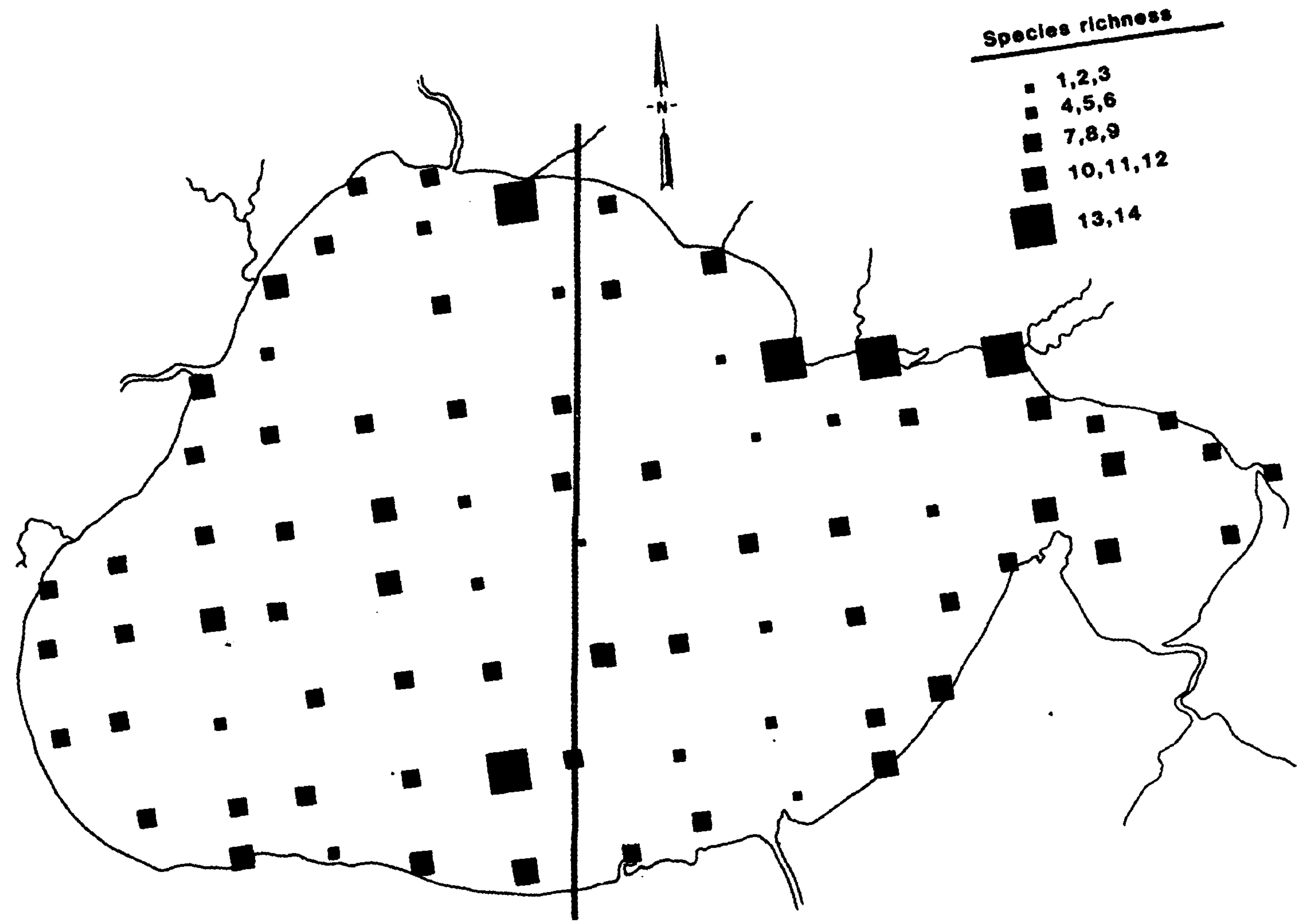

Figure 9. Total number of macrofaunal species (or taxa) found at each survey station in Lake Pontchartrain, LA, during the present study.

available, the distributions of major fauna were used to make the final decisions. This was the last criterion used in choosing the permanent monthly stations for benthic characterization.

We had initially projected two sampling sites in each of five geographic regions of the lake. However, after completing the selection process, we arrived at station locations shown in Fig. 10. There are, in fact, five geographic regions shown: northern, eastern, western, and southern regions, and a roughly south-central region. The southern region doubles as an "urban" region, and the northern and western regions as "riverine" regions. Fourteen sites are shown in Fig. 10, but the site marked "D" was the area selected for the dredging recovery experiment, and sites marked "S" are additional stations sampled seasonally. Data from the latter stations complement the information gained from the 10 characterization stations.

RESULTS AND INTERPRETATION

The overriding general conclusion from the Lake Pontchartrain benthic survey is that the largest portion of the lake bottom is relatively depauperate in terms of both species richness and density of macrofauna. Only 24 species or related groups were identified from 104-0.09 m^2 samples collected at 85 stations throughout the lake (Table 2). Chironomid larvae have been lumped throughout this study because of the difficulty of distinguishing species in this group at present. Mean number of species was 8.4 ± 0.3, and the maximum number ever found in a single sample was 14. One sample was totally devoid of macrofauna. The mean number of organisms per sample was 3116 $m^{-2} \pm 447$.

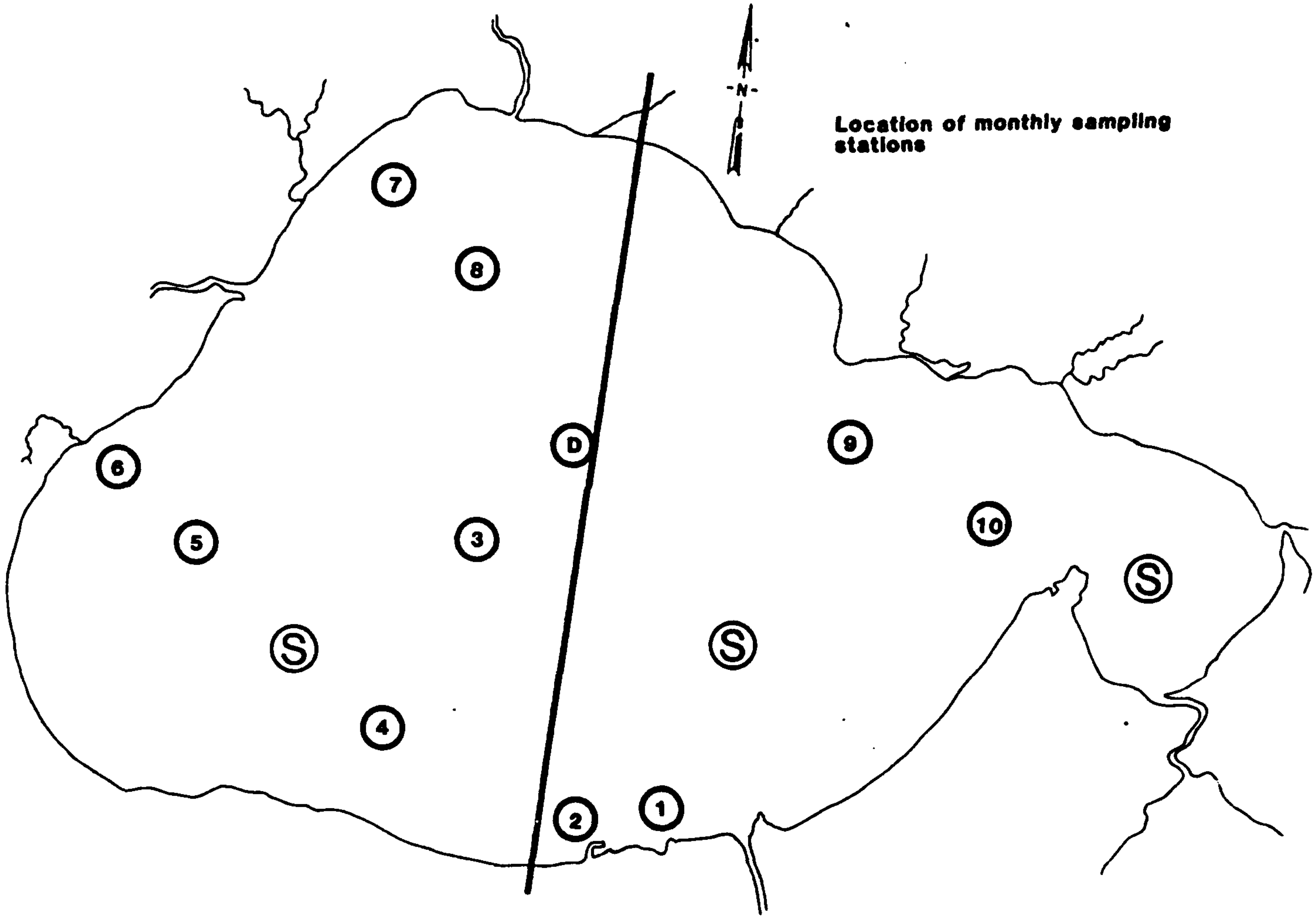

Figure 10. Location of the 10 monthly characterization stations (7-10), the dredging effects stations (D), and the 3 seasonal characterization stations (S) for the Lake Pontchartrain, LA, benthic study.

Table 2. Macrofaunal Abundance in Lake Pontchartrain, LA, in 1978

	Species Name	ΣN	N/m^2	SE	Percent of Total	Rank
1.	*Rangia cuneata*	3265	418.4	67.6	13.4	3
2.	*Mulinia pontchartrainensis*	5868	752.0	165.3	24.1	2
3.	*Macoma mitchelli*	520	66.6	12.0	2.1	7
4.	*Congeria leucophaeta*	647	82.9	20.4	2.7	8
5.	*Ischadium recurvus*	10	1.3	0.8		
6.	*Vioscalba louisianae*	8,422	1,079.3	307.9	34.6	1
7.	*Texadina sphinctosoma*	2,007	257.2	62.1	8.3	4
8.	*Hypaniola florida*	1,649	211.3	49.3	6.8	5
9.	*Laeonereis culveri*	20	2.6	1.4		
10.	*Nereis succinea*	28	3.5	1.0		
11.	*Parandalia americana*	175	22.4	5.2	0.7	9
12.	Oligochaetes	11	1.4	0.5		
13.	Nemerteans	109	14.0	1.6	0.4	10
14.	*Mysidopsis almyra*	15	1.9	1.1		
15.	*Edotea montosa*	76	9.7	1.9		
16.	*Cyathura polita*	50	6.4	2.0		
17.	*Monoculodes edwardsi*	12	1.5	0.6		
18.	*Corophium lacustre*	50	6.4	2.6		
19.	*Grandidierella bonnieroides*	8	1.0	0.4		
20.	*Gammarus tigrinus*	13	1.6	1.3		
21.	*Cerapus* sp.	2	0.3	0.2		
22.	*Rhithropanopeus harrisii*	9	1.1	0.4		
23.	*Callianassa jamaicensis*	1	0.1	0.1		
24.	Chironomids	1,348	172.7	18.1	5.5	6
	TOTALS	24,315	3,116.0			

Note: 6 highest ranking species comprise 92.78% of total;
8 highest, 97.58%; 10 highest, 98.75%.

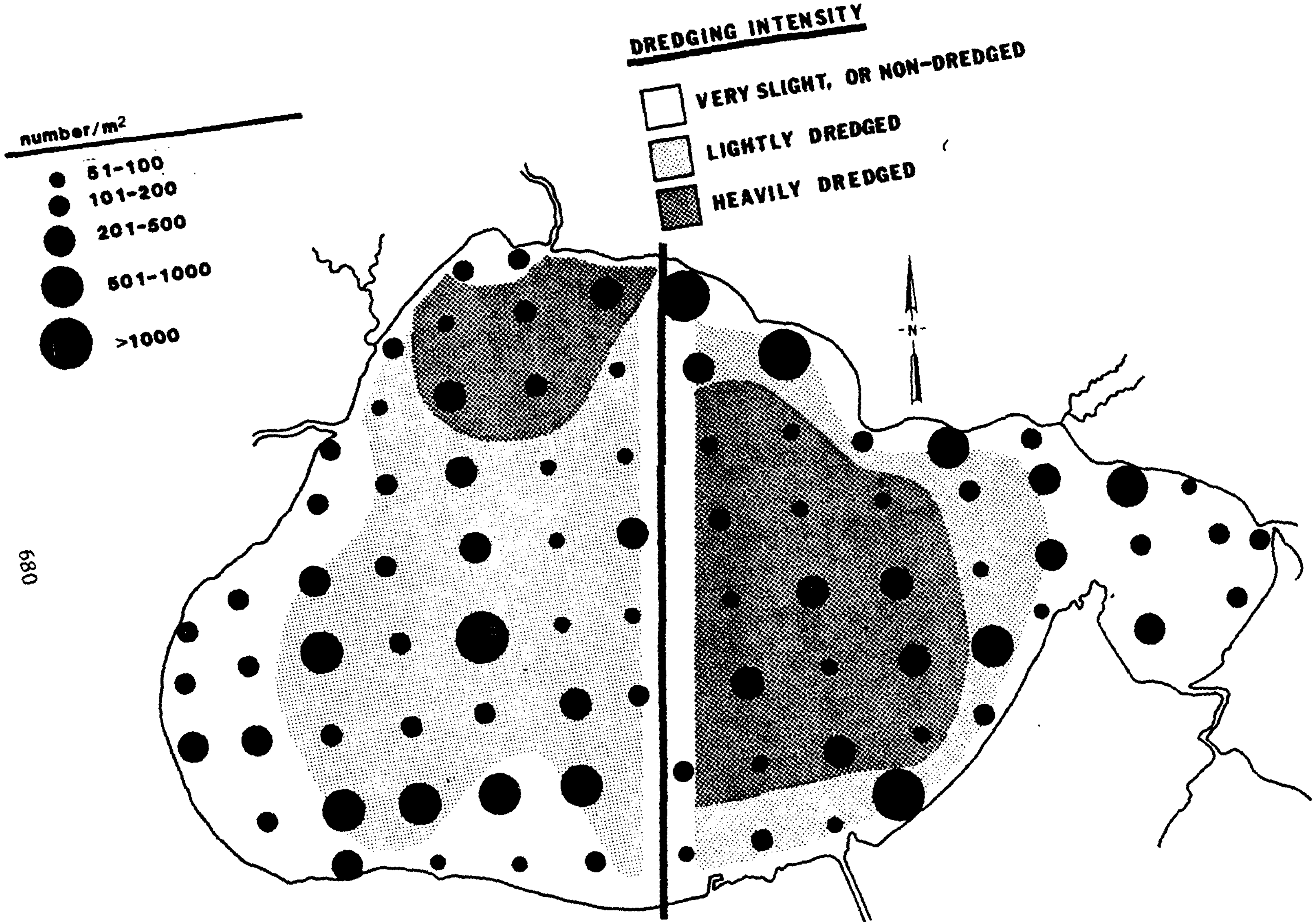

Figure 11. Comparison of the distribution of the total benthic macrofaunal organisms and the distribution of relative shell dredging intensity through Lake Pontchartrain, LA

Biomass of these macrobenthic organisms was calculated to equal an average of 3.3 g/m^2 ash free dry weight (afdw). Eight species dominated the macrobenthic community and accounted for 97% of the total organisms collected. Average Shannon-Wiener diversity for all samples was 1.37 ± 0.04 $[H' = -\Sigma p_i(\log_e p_i)]$.

A map of estimated, relative dredging intensity was prepared in which the lake was divided into three categories of dredging: (a) very slight or nondredged, (b) lightly dredged, and (c) heavily dredged. Information used to establish these areas included the dredging industries' own self-imposed dredging zones, and safety and sanctuary restrictions imposed on the industry by the Louisiana Wildlife and Fisheries Commission.

Evidence gathered subsequent to the survey indicates that the edge zone of Lake Pontchartrain is dissimilar in several respects to the open lake. For example, we have preliminary data indicating a zone of peak density of macrobenthos between 1/4 km and 1 km from shore. These data were collected along a transect from mid-lake (Station D) east-northeast to the shoreline west of Bayou Lacombe.

One of the most striking distinctions between macrofauna in the open lake and at the edge zone is the difference in size of the dominant bivalve <u>Rangia</u> <u>cuneata</u>. Shallow areas (especially at the north shore) are dominated by large <u>Rangia</u> (30 mm and above), but clams larger than 10 mm were very rare at all 85 open lake stations during the survey. This same phenomenon was previously reported by Tarver and Dugas (1973).

Boesch (1973), in a study of community structure of macrobenthos, characterized the Hampton Roads, Virginia, estuarine sampling areas as being heavily influenced by activities related to shipping, oil pollution,

dredging, and municipal and industrial waste disposal. The 141 grab samples yielded a total of 168 recognizable macrofaunal taxa (oligochaetes are lumped). An average of 23.0 ± 3.7 species were present at each sampling at the mud stations, which had a species diversity of 1.59 ± 0.26.

In a study of the effects of pollution on estuarine animals in Apalachicola Bay, Florida (Livingston et al. 1978), the invertebrates studied had an average diversity of 1.34 ± 0.36, with mean number of species 11.7 ± 3.8.

Various studies in the Baltic, which has large areas of low salinity, show a range of values related to pollution levels. Rosenberg and Möller (1979), in a relatively unpolluted area on the west coast of Sweden, found diversities varying from 2.29 to 2.86, with 39 species present (Hydrobiids are lumped). Leppäkoski (1975) studied low salinity, polluted areas on the west coast of Sweden and the south west coast of Finland and found an average diversity of 1.48 ± 0.08, with 6.0 ± 0.3 species present (chironomids and oligochaetes are each lumped).

Two trends may be observed in these studies. The two areas with slightly higher salinities ($\simeq$ 15°/₀₀), Hampton Roads and Apalachicola Bay, had more species present than the lower salinity areas of the Baltic and Lake Pontchartrain. Remane (1934) pointed out the decline in species with lowered salinity, with a species minimum at 6-7°/₀₀. Elmgren (1978) showed a species minimum in the Baltic at 3-4°/₀₀. In areas of similar salinity, however, a decline in species diversity occurs with increasing pollution, as is evidenced in the contrast between the two low salinity habitats on the west coast of Sweden.

The species diversity of Lake Pontchartrain macrofauna was not significantly different ($P \geq 0.05$) from that of the Hampton Roads area

(Boesch 1973), the Apalachicola Bay (Livingston et al. 1978), or the polluted areas of the Baltic (Leppäkoski 1975, Ankar and Elmgren 1976). It was, however, significantly different from the unpolluted Baltic areas (Rosenberg and Möller 1979) with similar salinity regimes.

One study (Ruggiero and Merchant 1979) of the Patuxent River showed a change in diversity with changes in substrate. The diversity ranged from a high of 2.69 to a low of 0.14. Ruggiero and Merchant characterized these levels of diversity, ranging from moderately to severely polluted, as indicating increasing stress from a pollutant. If the changes due to substrate were held constant, their study indicated only moderate pollution despite the lower diversities.

The effects of salinity stress in brackish waters probably interacts with any effects of present pollution levels. It is doubtful that the diversity of Lake Pontchartrain, with its present salinity regime, could ever be higher than 2.4 to 2.8.

It is difficult to compare these areas for density or biomass of organisms. Different sampling gear, sampling techniques, and sample handling techniques such as live or preserved sieving, size of sieves demarcating the macrofauna-meiofauna division, and use of splits or whole samples tend to cause differences that may or may not be representative of actual community differences. The use of measures of community structure such as species diversity or species richness enables us to compare these areas with some degree of confidence because absolute numbers do not affect those measures so long as sample size and number of samples are adequate.

When the macrofauna data were analyzed by a clustering technique, the greatest dissimilarity coefficient appeared to separate the collections

from heavily dredged and polluted areas from samples obtained at less stressed areas. At lower levels of dissimilarity, seven distinct groups of stations appear. These groups differ in location within the lake, in abundance, and in diversity. Cluster A (Table 3, Fig. 12) contains stations with significantly higher abundance than any other group. Because of the effect of high dominance, these stations also exhibit significantly lower diversity. Clusters B, C, and D all show values for abundance not significantly different from the mean. Cluster B consists mostly of "edge" stations along the north and west shores and has significantly higher diversity than the other clusters. Clusters C and D might be considered as subgroups of one cluster because they are separated at a fairly high level of similarity. It is, however, a natural separation into an eastern, higher salinity group of stations with lower diversity (C), and into a western, lower salinity group with average diversity (D). Cluster E, the group nearer New Orleans, exhibits an urban influence, with significantly lower abundance and average diversity. Cluster F includes stations somewhat impacted by dredging, with lower abundance and average diversity. Cluster G includes those stations most severely impacted, with extremely low abundance (two orders of magnitude lower than the others), and significantly low diversity.

Analysis of the distribution of dominant species as the dependent variable in a stepwise multiple regression using a variety of environmental parameters as independent variables (dredging intensity, time of collection, conductivity, organic carbon, and sediment distribution) showed that different species were sensitive to different parameters. Figures 13, 8, 14, and 11 show macrofaunal distribution with respect to

Table 3. Mean Abundance and Diversity of Clusters for Lake Pontchartrain, LA, 1978

Cluster	A	B	C	D	E	F	G
Abundance							
$\bar{X}/m^2$	9,676.35	2,254.79	3,289.60	2,695.52	1,260.83	760.93	58.55
SE/m^2	1,568.52	252.71	209.09	246.29	113.45	70.91	22.82
Diversity							
H	1.2495	1.6221	1.1541	1.3502	1.4572	1.4159	0.6381
SE	0.1027	0.0802	0.1592	0.0560	0.0884	0.1050	0.2536

TOTAL Lake Pontchartrain:

	Mean ± SE	95% Confidence Limits
Abundance	3,135.03 ± 443.23	2,271.01 - 4,035.08
Diversity	1.372 ± 0.040	1.294 - 1.450

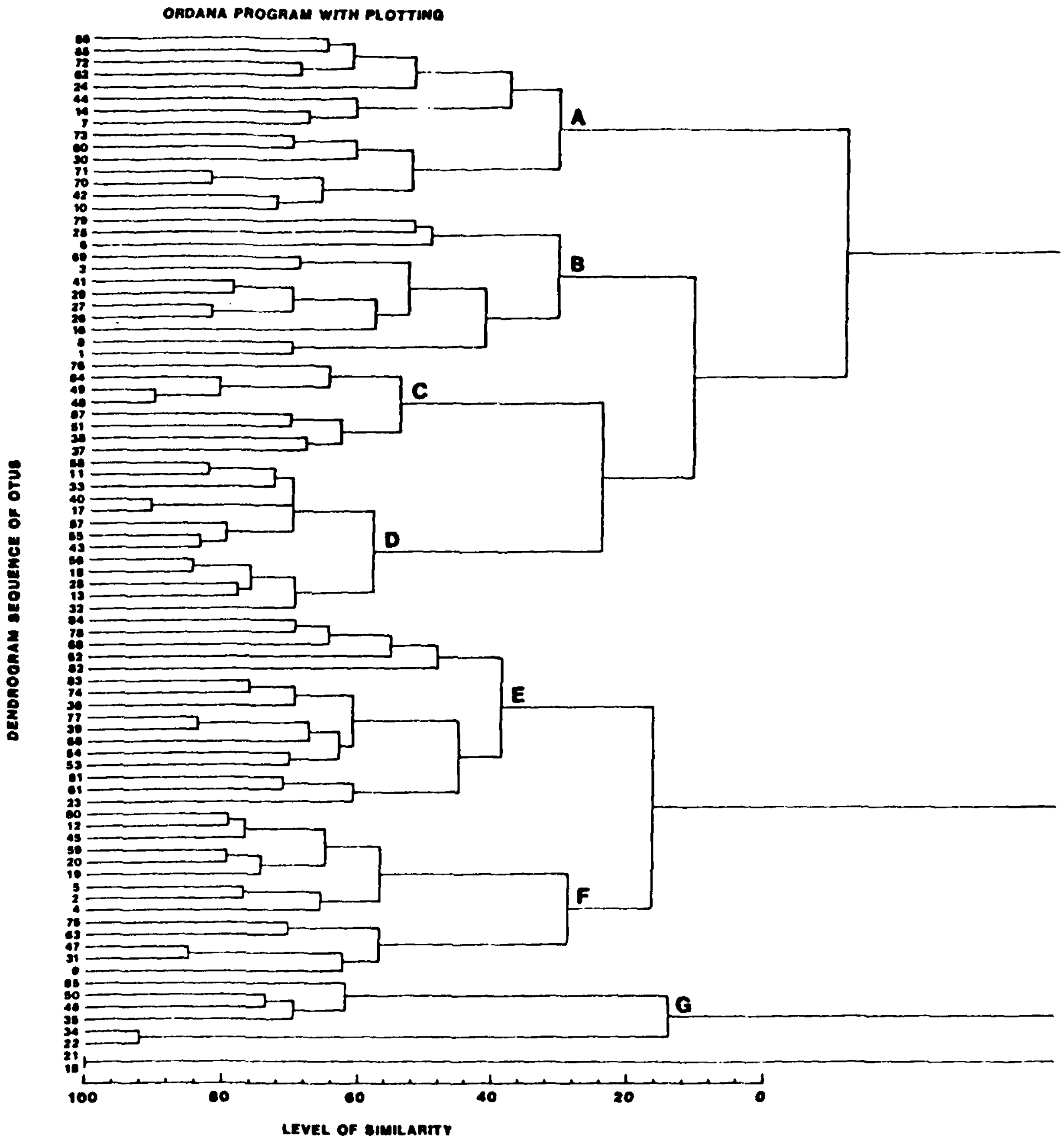

Figure 12. Dendrogram of stations in Lake Pontchartrain, LA, during this study.

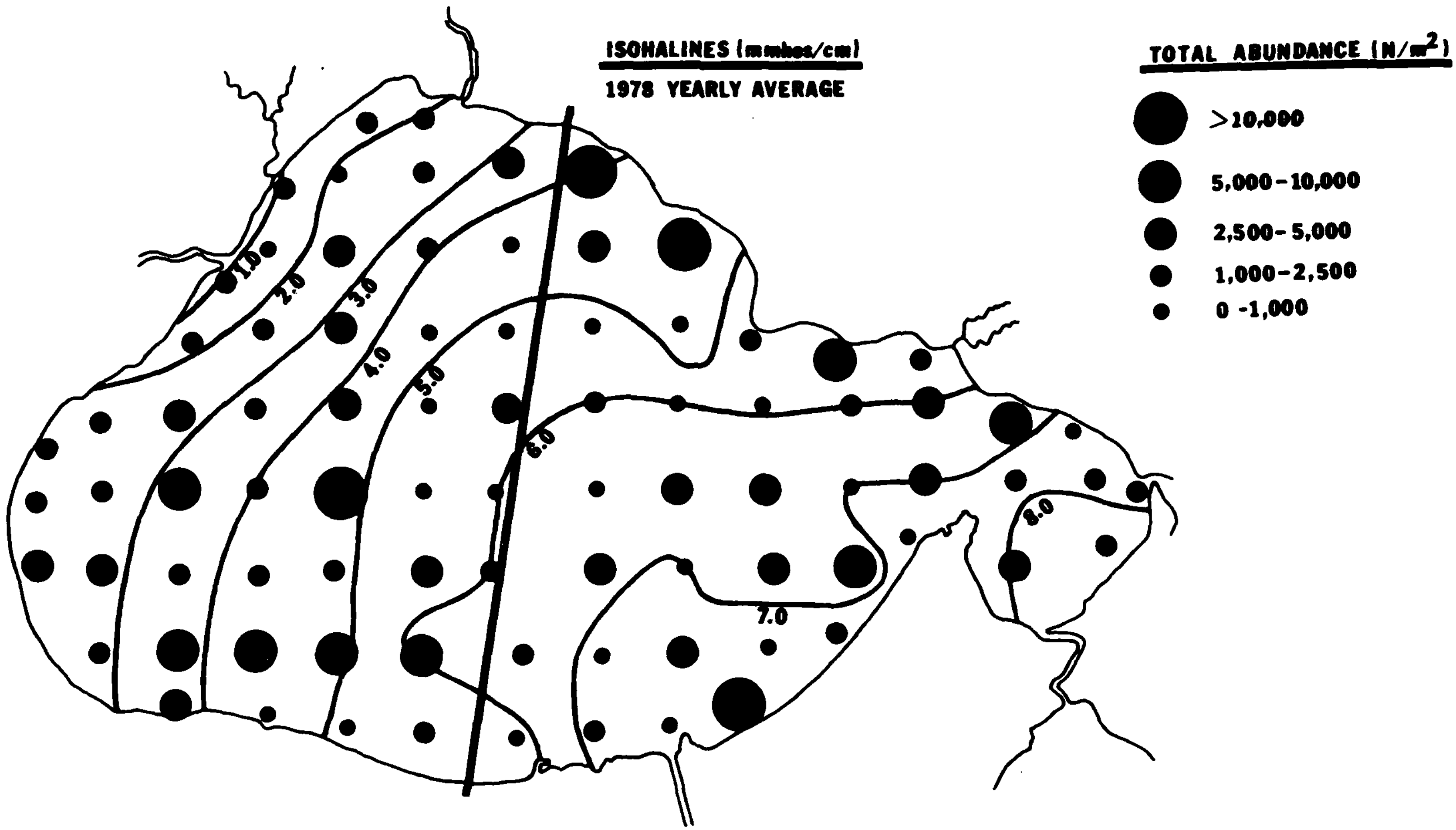

Figure 13. Average annual isohalines in Lake Pontchartrain, LA, for 1978.

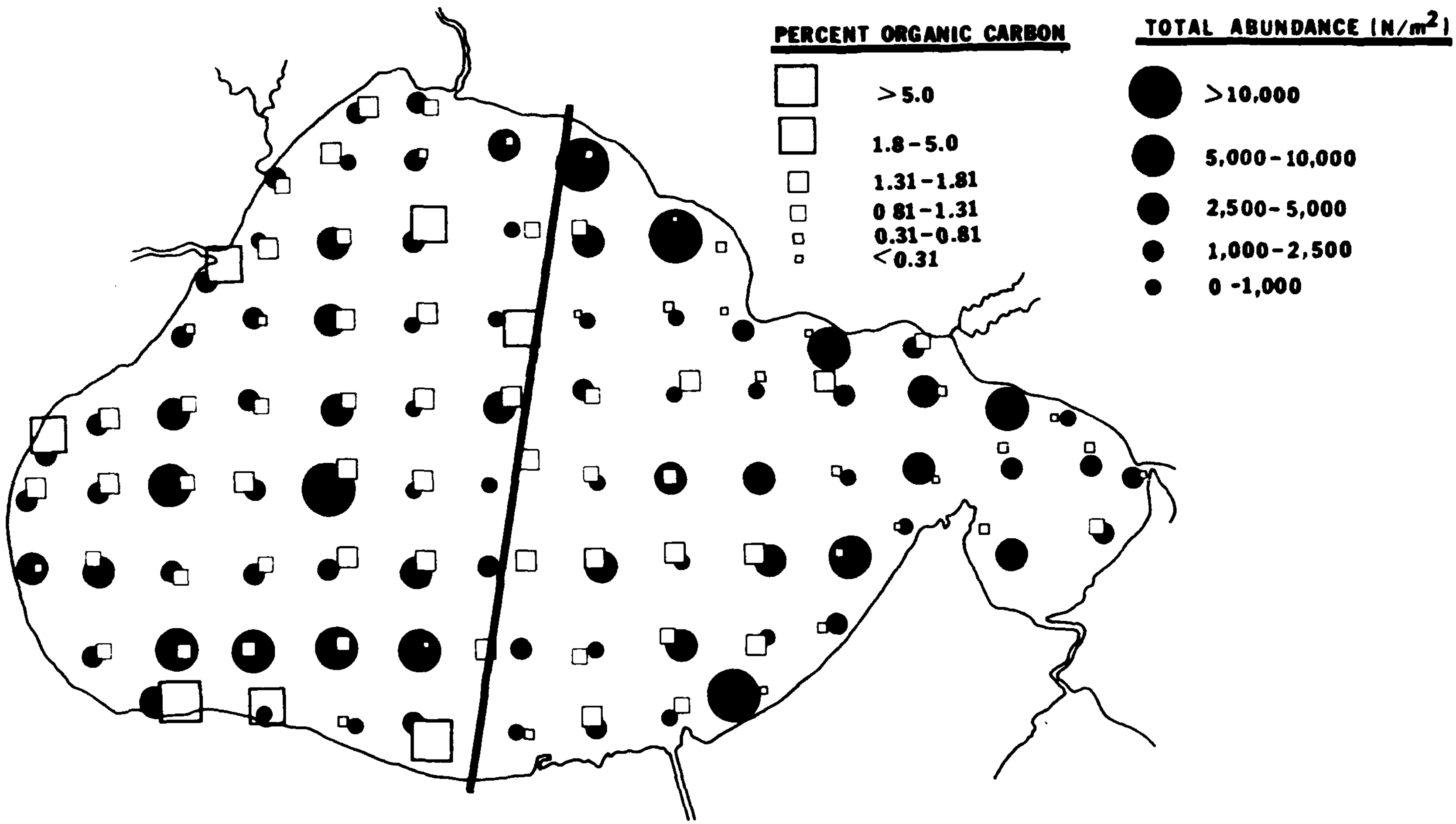

Figure 14. Organic carbon distribution of sediments in Lake Pontchartrain, LA, from 1978 survey.

four of these parameters. Table 4 summarizes the units of the multiple regression for the eight dominant species. When all species were considered together, the variability in their combined distribution was most significantly explained by the estimated intensity of dredging at each sampling site. This parameter reduced the variability in the combined distribution by 14%, which is considered highly significant, given the large variability. The second most significant factor, time of collection, was not significant in controlling variability of distribution. The third most significant factor, conductivity, lost significance in total distribution because some species preferred higher and some preferred lower conductivities, and, when combined, they cancelled each other out. The lack of significance of the fourth factor, organic carbon, in both the distribution of the individual species and in the distribution of total numbers of animals is probably related to the relatively even levels of organic carbon across the lake. The fifth factor, grain size of the sediment, was significant in only one case, the polychaete Hypaniola florida, which, in this study, appeared more frequently in the coarser sediments (Appendix Fig. 1).

DISCUSSION

The results of this survey indicate that the Lake Pontchartrain macrobenthic community is in relatively poor condition (at least in the open lake), and we believe that this condition represents a historical decline. The lack of quantitative "before" data precludes our making a definitive statement about the timing of this decline; however, we hypothesize that the change in "health" of the benthic community coincided

Table 4. Results of Stepwise Multiple Regression

Species	*Rangia*	*Mulinia*	*Macoma*	*Congeria*	*Vioscalba*	*Texadina*	*Hypaniola*	Chironomids	Total
Factor 1	Cond.	Cond.	Cond.	Cond.	Cond.	Cond.	Grain Size	Cond.	Dredging
F	22.48	33.16	37.72	16.57	13.26	6.97	14.73	29.04	8.97
Prob. F	0.0001	0.0001	0.0001	0.0001	0.0005	0.0101	0.0003	0.0001	0.0037
Factor 2	Dredging	Dredging	Dredging	Organics	Organics	Grain Size	Organics	Dredging	Cond.
F	5.96	2.85	3.29	0.60	5.37	3.84	6.69	20.64	1.75
Prob. F	0.0170	0.0957	0.0738	0.4397	0.0232	0.0539	0.0116	0.0001	0.1897
r^2 for all factors	0.2342	0.4241	0.3975	0.1874	0.2588	0.2342	0.4155	0.4444	0.1449

with the gradual increase in cultural perturbations that have resulted in a decline in general lake productivity.

Within-lake primary production overall is generally lower than would be expected, given the average nutrient levels in the water column (Witzig and Day, Chapter 2; Dow and Turner, Chapter 7). Chlorinated hydrocarbons have been detected in the water column of Lake Pontchartrain (United States Geological Survey 1978), and there is evidence that these chemicals can inhibit primary production (Moore and Harriss 1972).

The best evidence for a probable change in the macrofaunal community on the lake bottom itself is the fact that large living clams are virtually absent from this area, as shown by their absence in piles of dredged shells (Tarver 1972). Another indicator of current problems is that the reported average diversity (using the Shannon-Wiener formula) of macrobenthos in the open lake ($\sim$1.4, present study) is well below the minimum level of three that has been reported to indicate healthy (unpolluted) estuarine benthic communities (Ruggiero and Merchant 1979). No comparable data are available from previous studies of Lake Pontchartrain for comparison.

We strongly advocate a continued effort to quantify rates of secondary productivity of benthic organisms in the open lake and at lake edge. The connection between these organisms and the demersal nekton that comprise the major portion of the higher consumers in the lake should also be documented.

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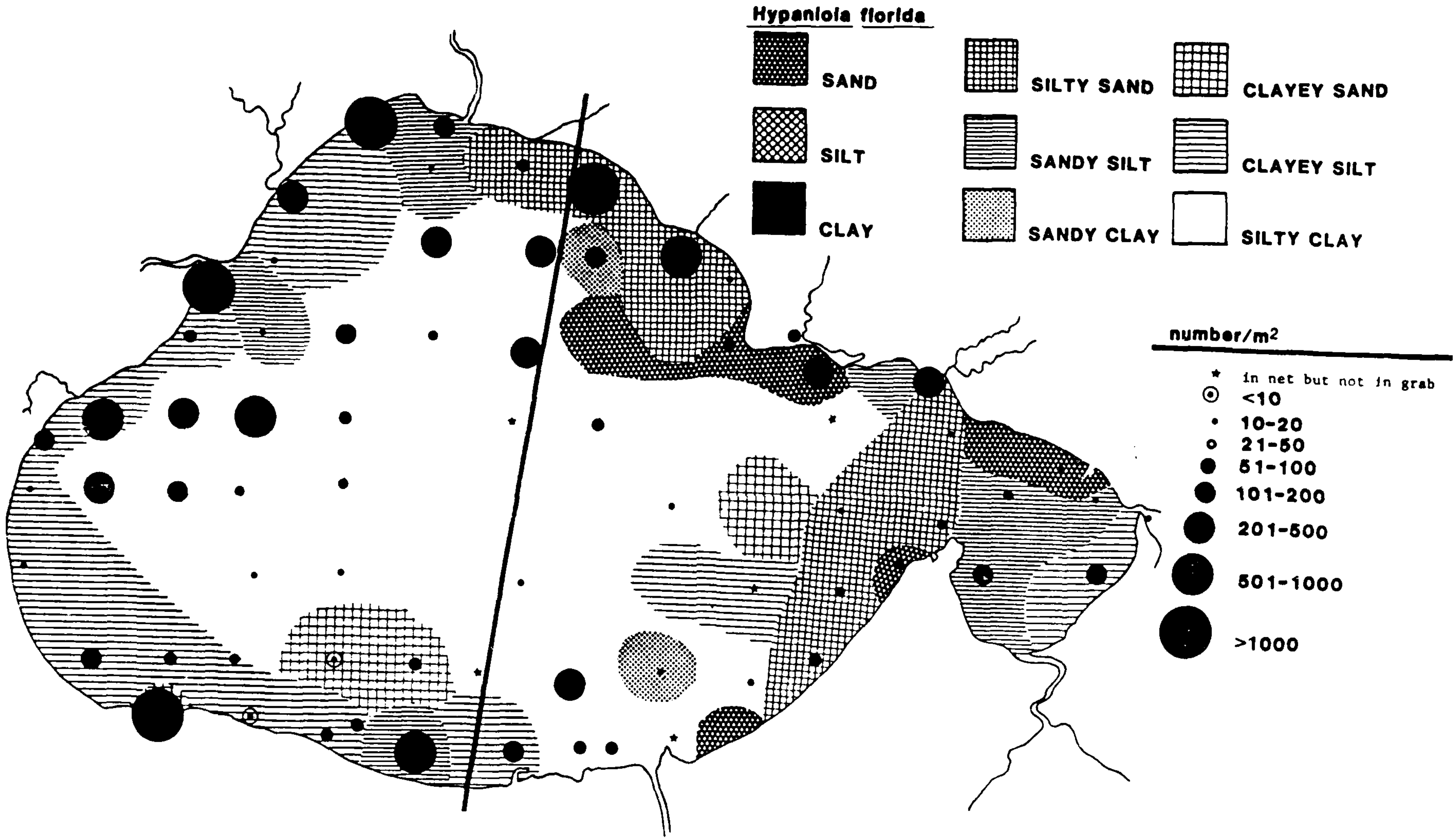
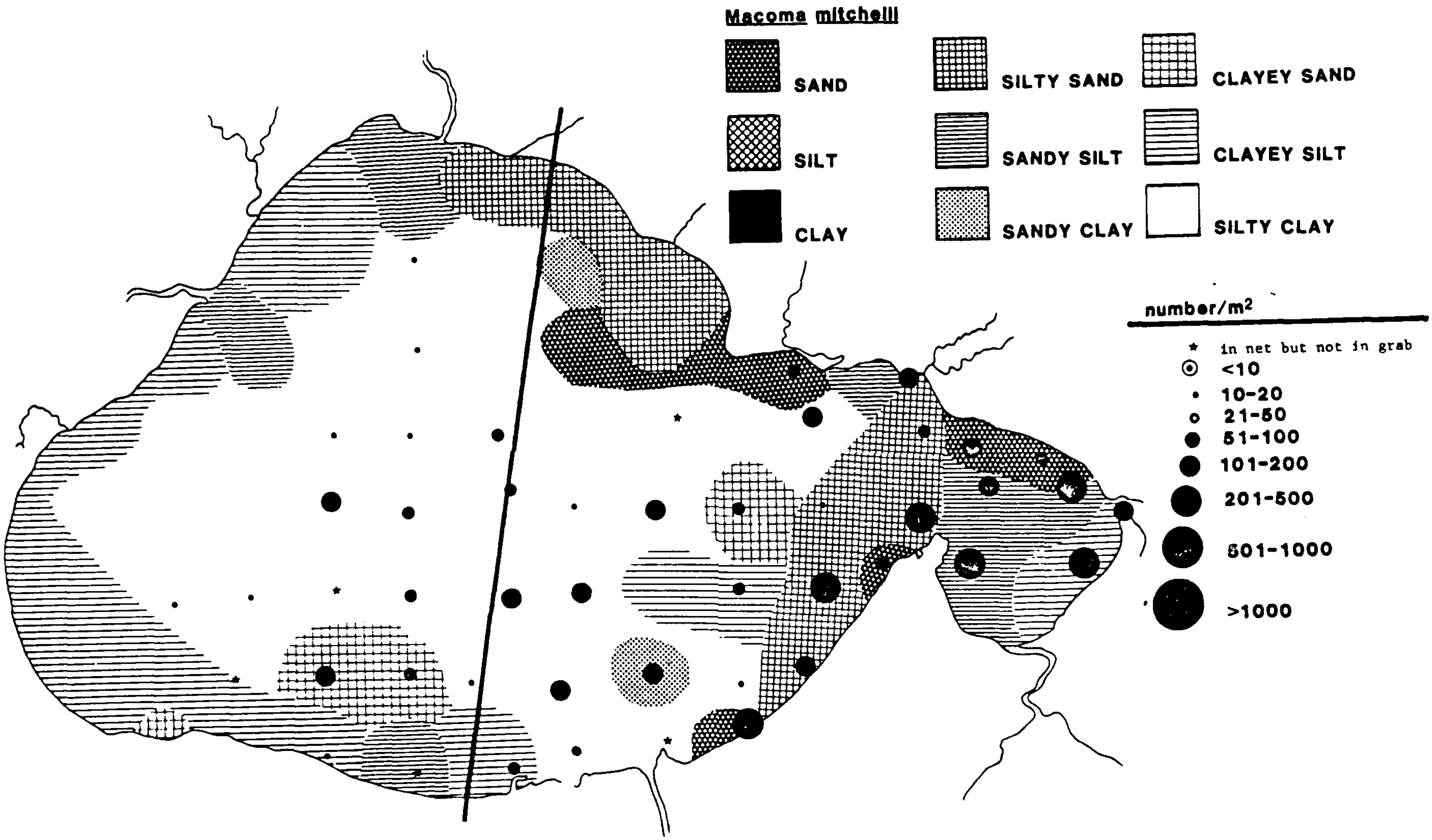
Another view of Rangia shell loading

APPENDIX

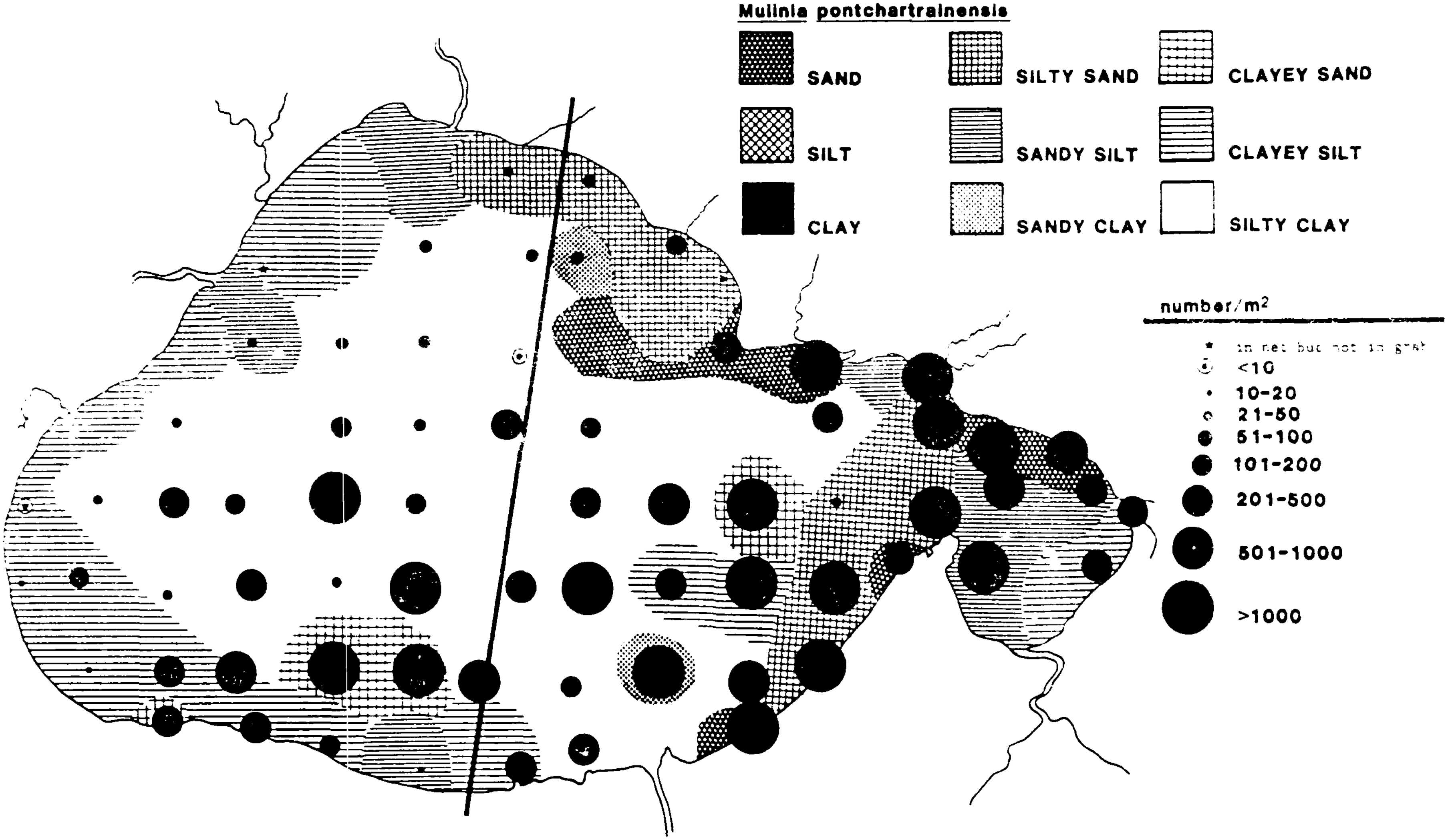
SELECTED SPECIES DATA



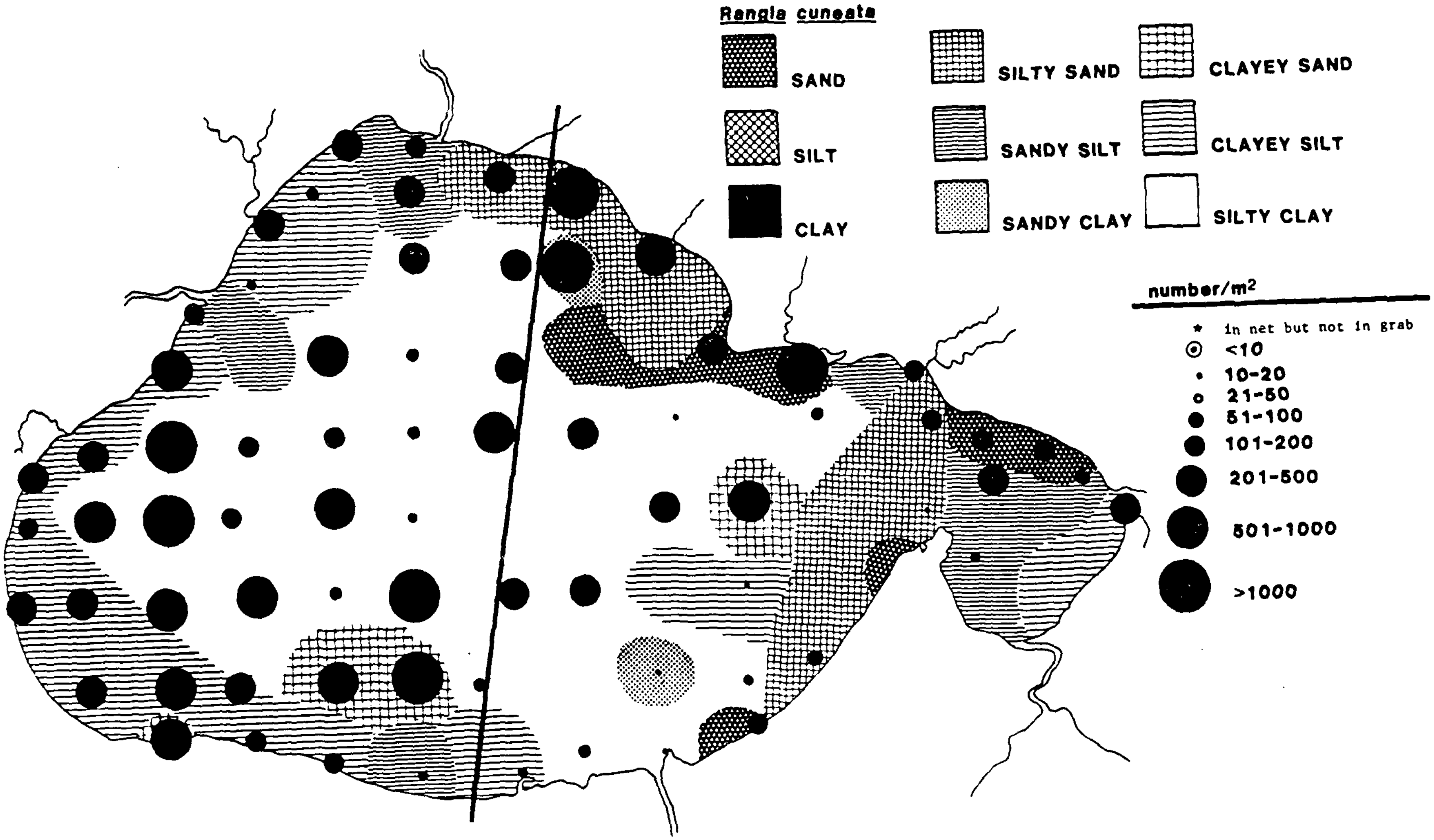
Appended Figure 1. Distribution of <u>Hypanioia florida</u> in Lake Pontchartrain, LA, as determined during the present study.



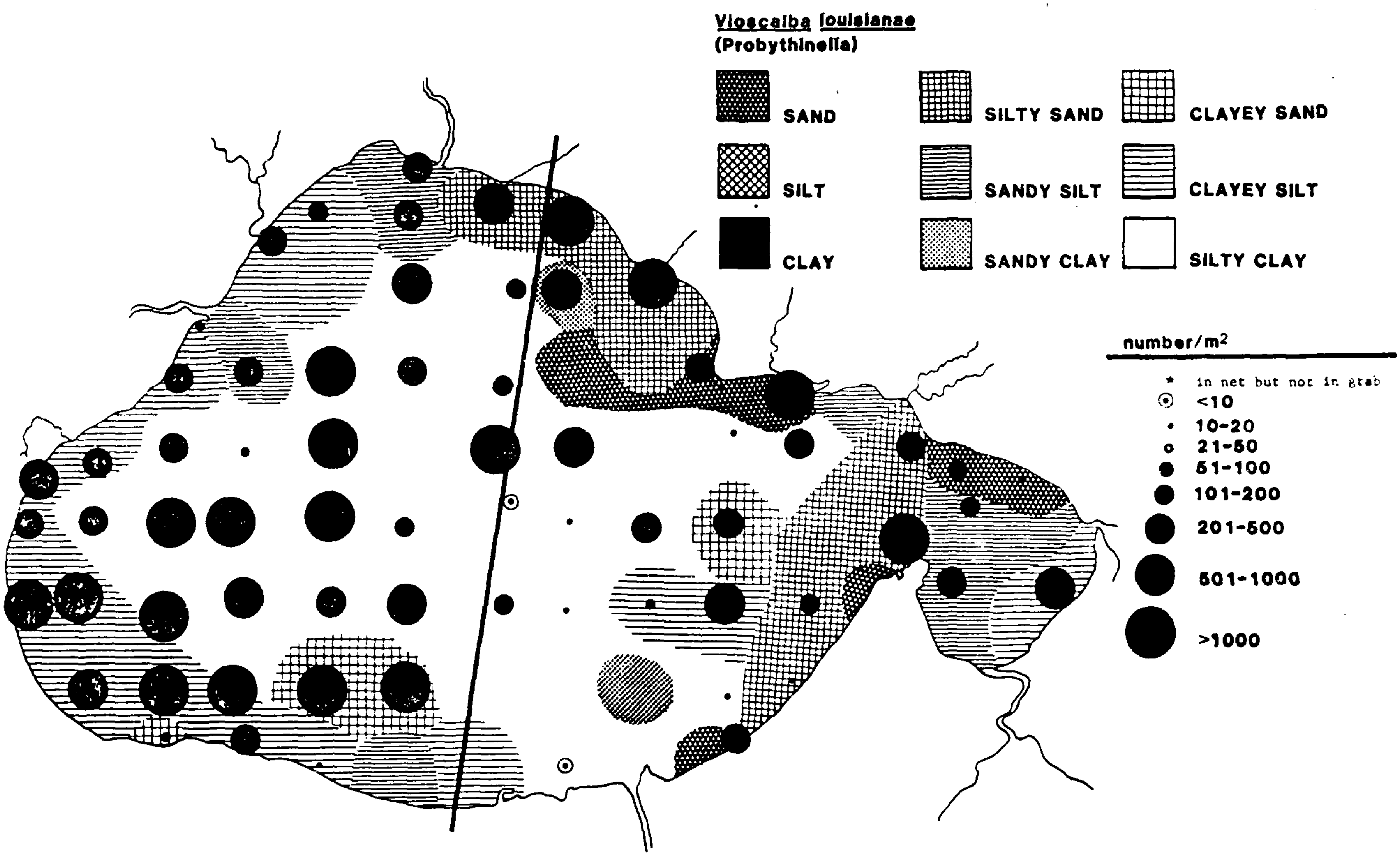
Appended Figure 2. Distribution of *Macoma mitchelli* in Lake Pontchartrain, LA, as determined during the present study.



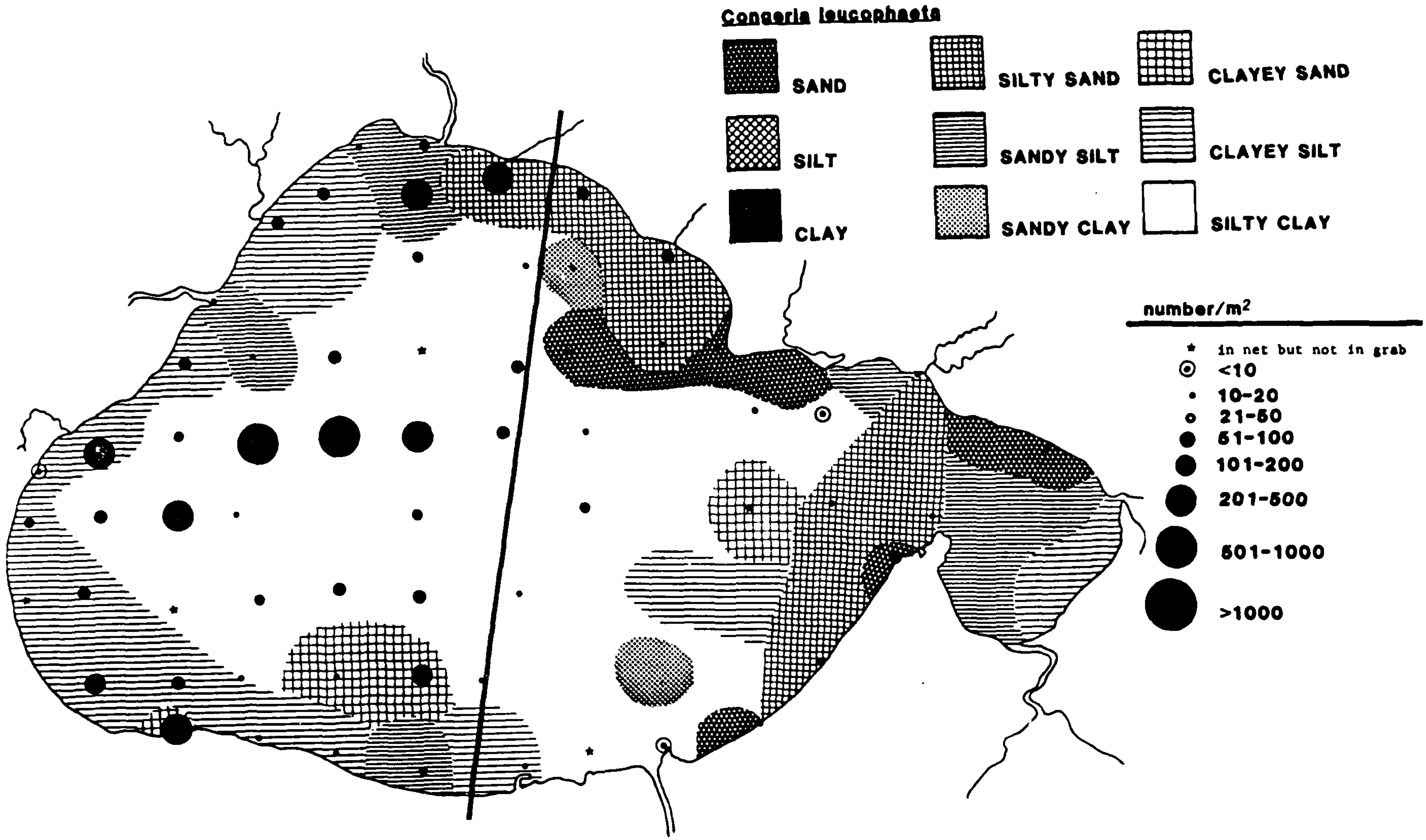
Appended Figure 3. Distribution of Mulinia pontchartrainesis in Lake Pontchartrain, LA, as determined during the present study.



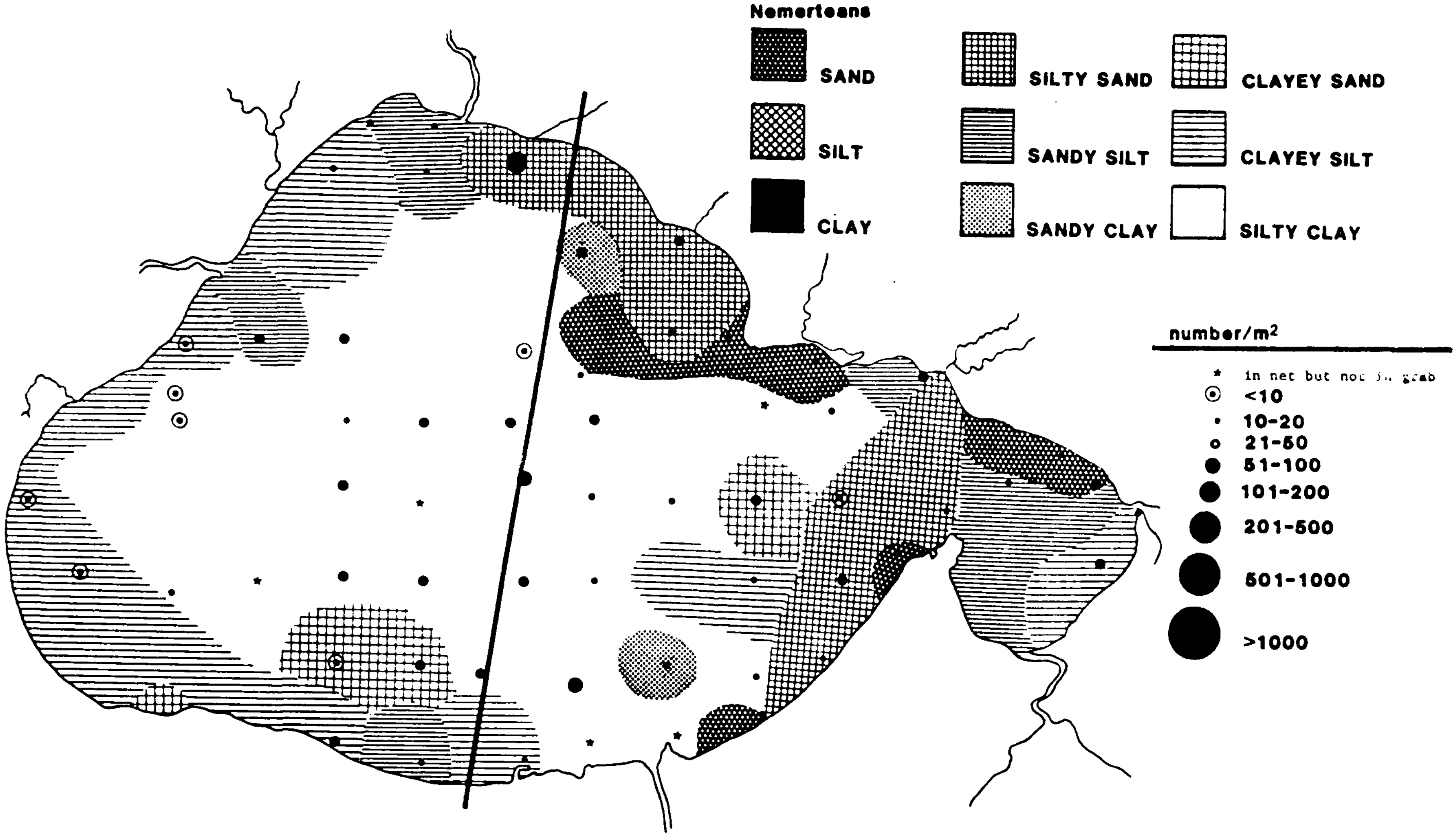
Appended Figure 4. Distribution of *Rangia cuneata* in Lake Pontchartrain, LA, as determined during the present study.



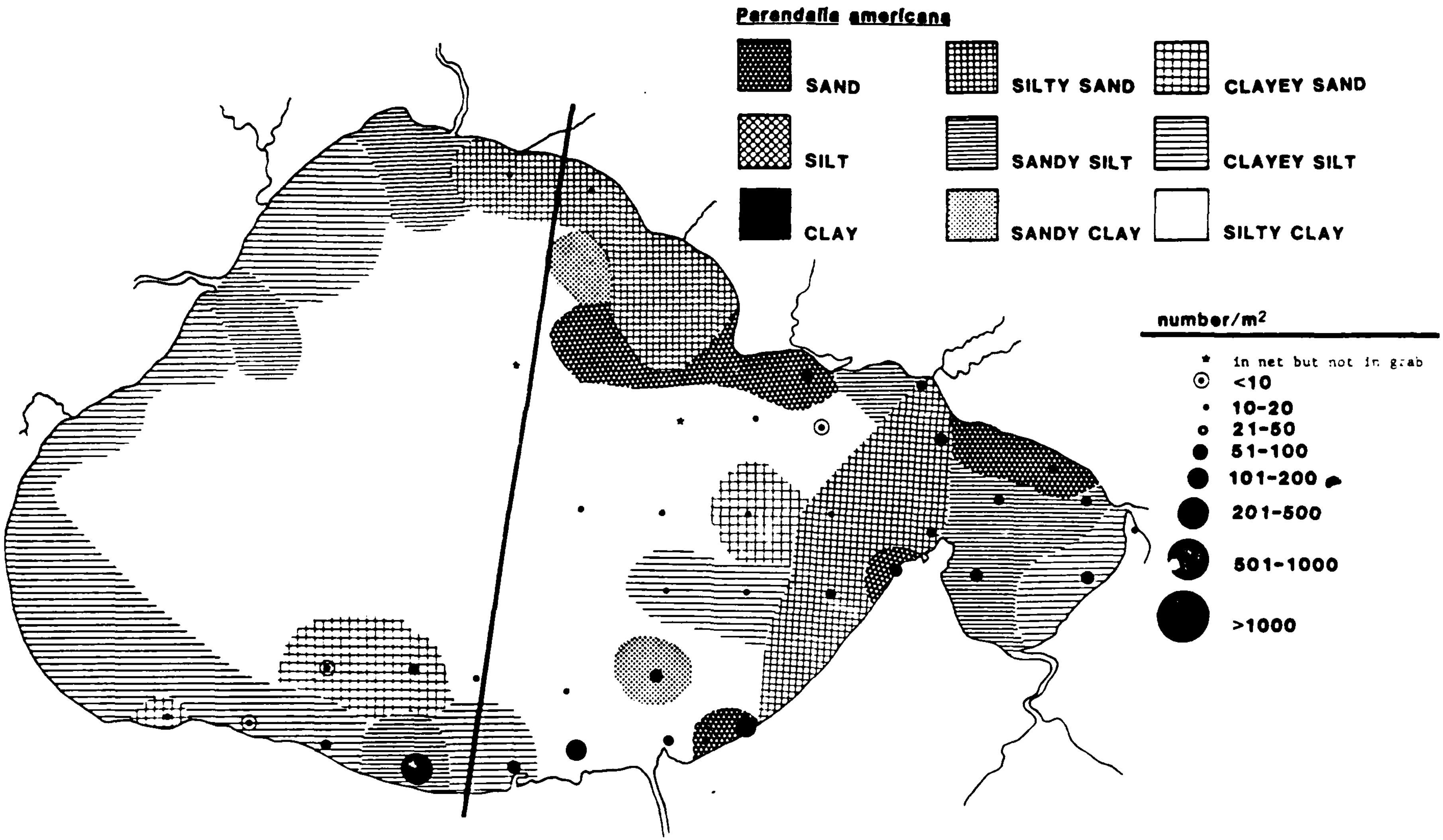
Appended Figure 5. Distribution of <u>Vioscalba louisianae</u> in Lake Pontchartrain, LA, as determined during the present study.



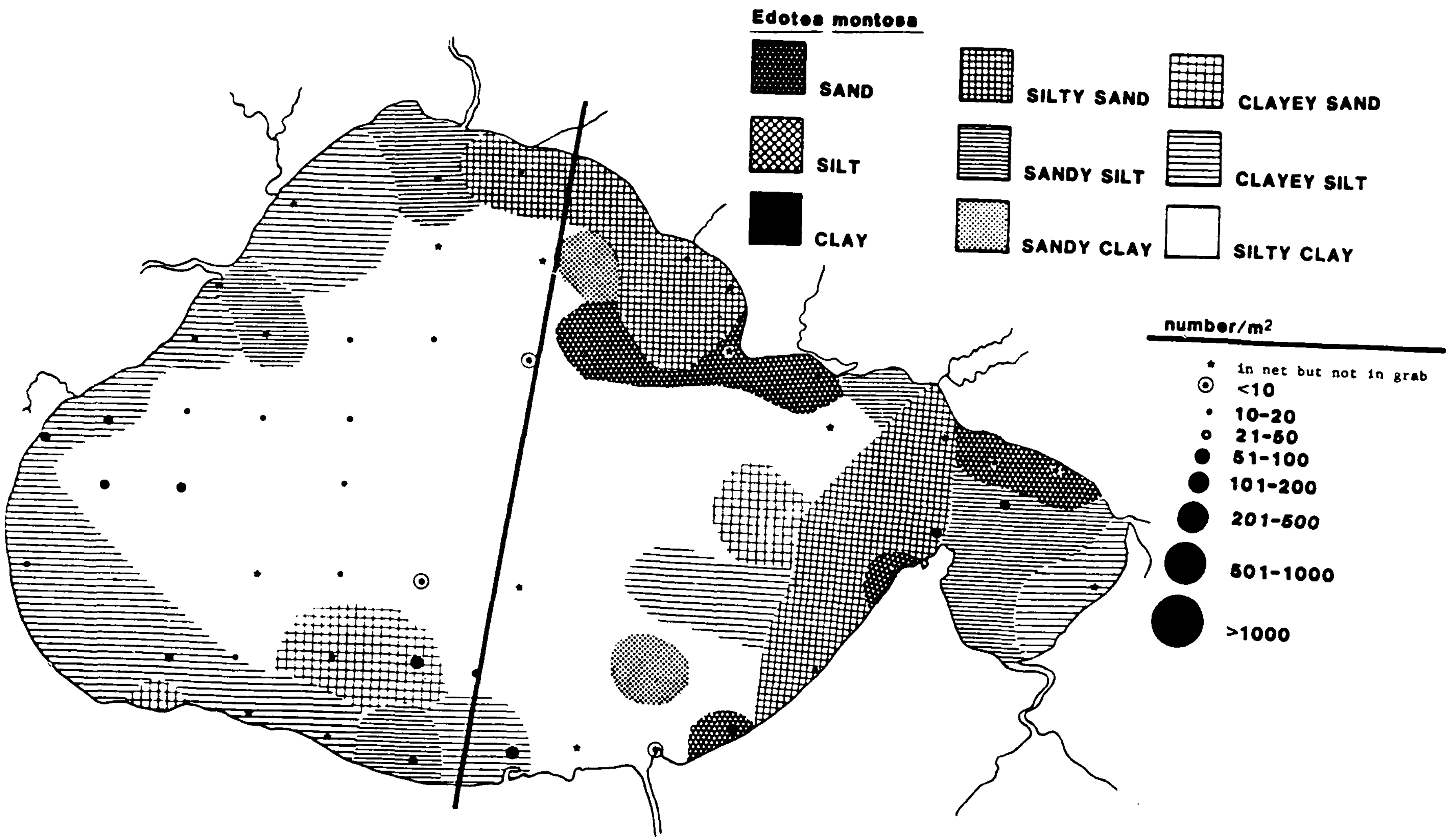
Appended Figure 6. Distribution of Congeria leucophaeta in Lake Pontchartrain, LA, as determined during the present study.



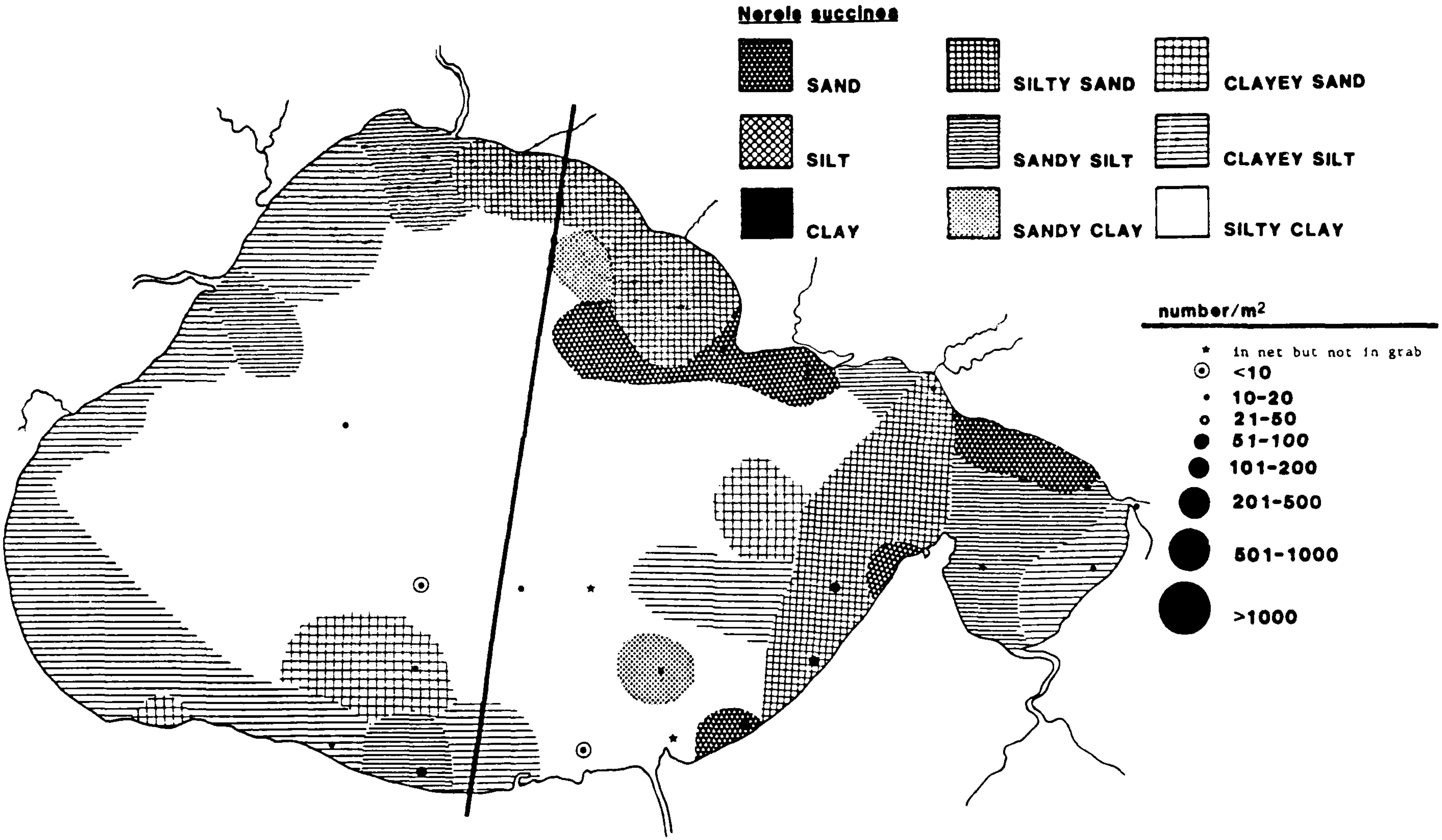
Appended Figure 7. Distribution of Nemerteans in Lake Pontchartrain, LA, as determined during the present study.



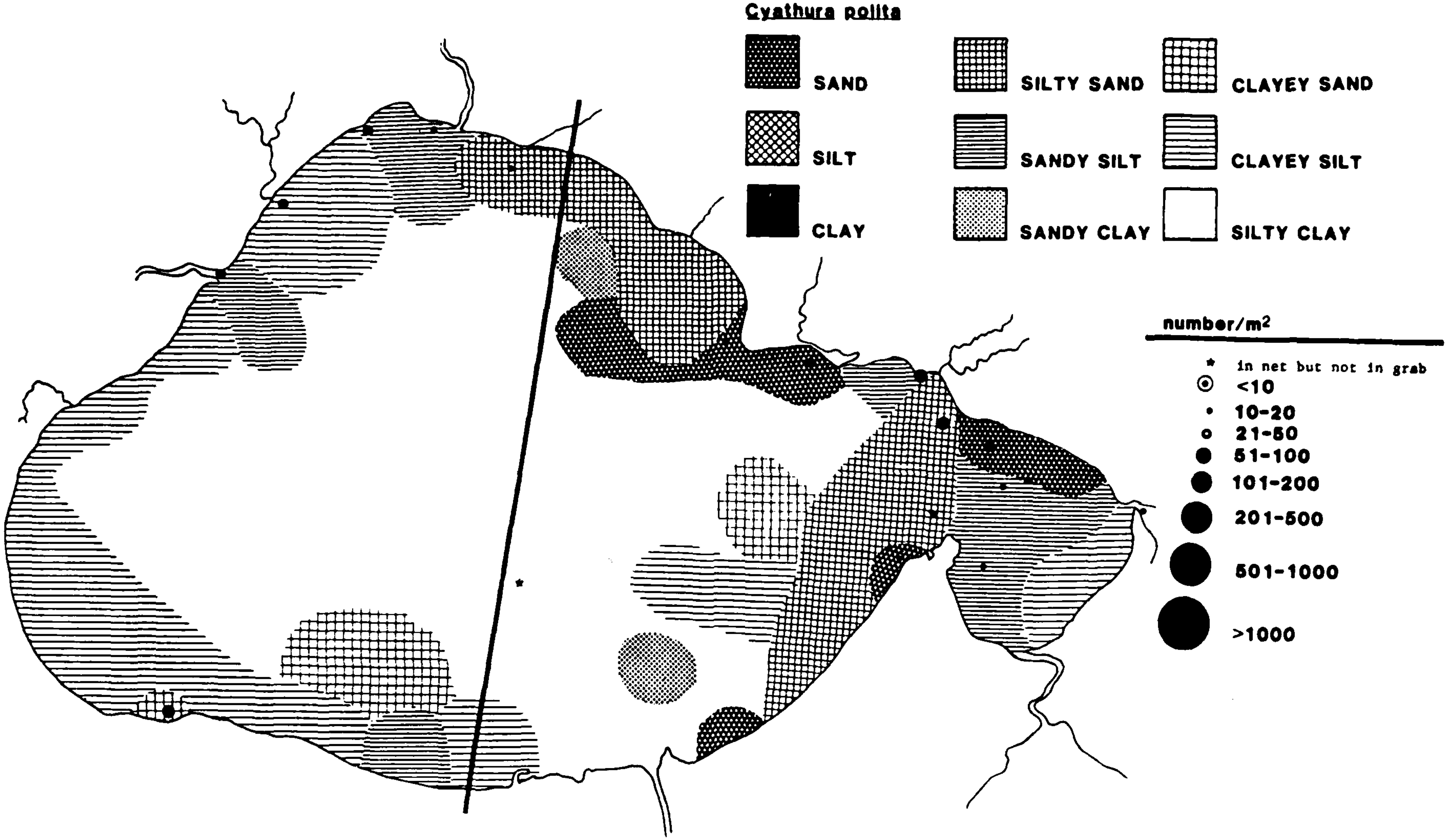
Appended Figure 8. Distribution of Parandalla americana in Lake Pontchartrain, LA, as determined during the present study.



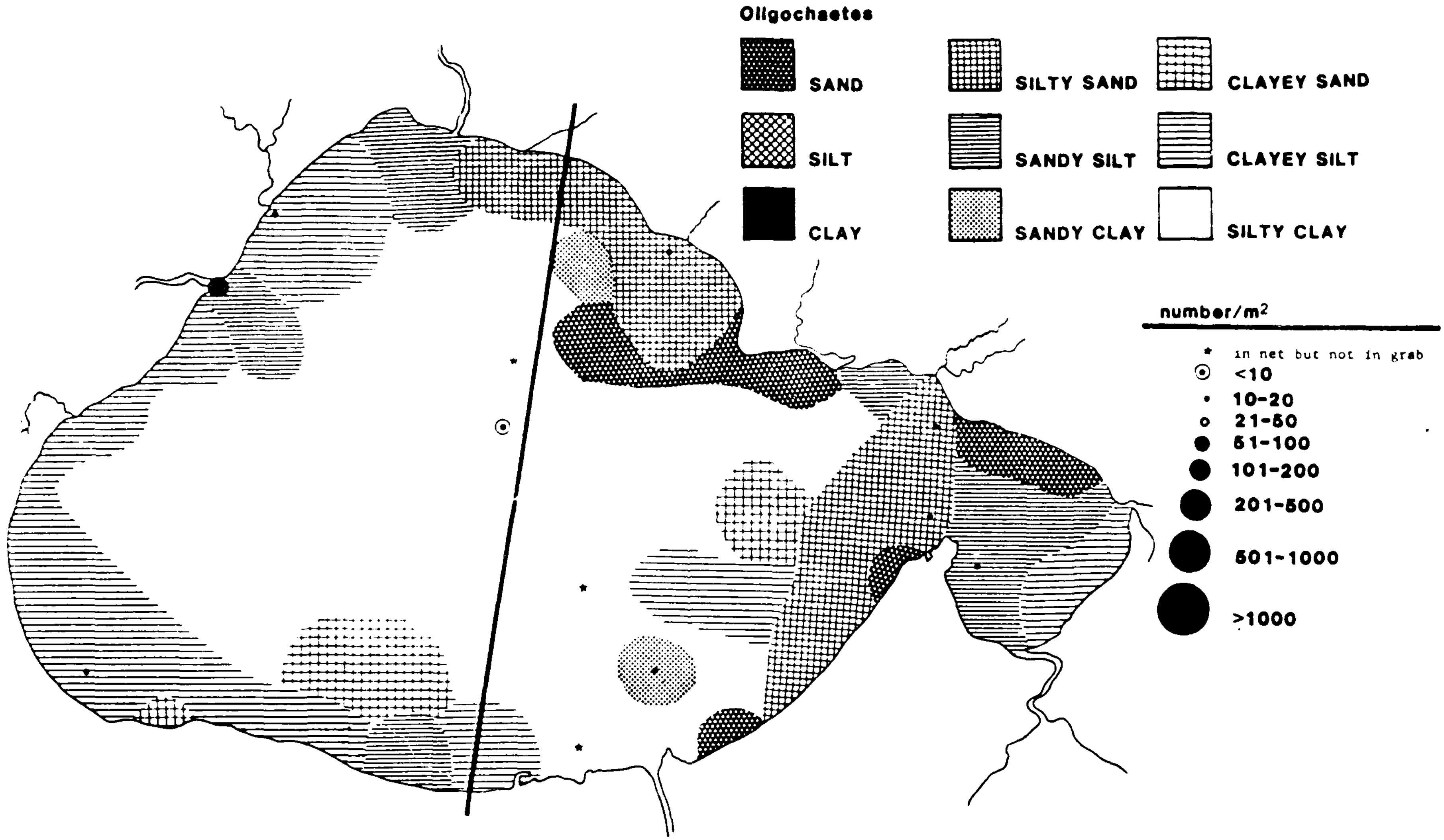
Appended Figure 9. Distribution of Edotea montosa in Lake Pontchartrain, LA, as determined during the present study.



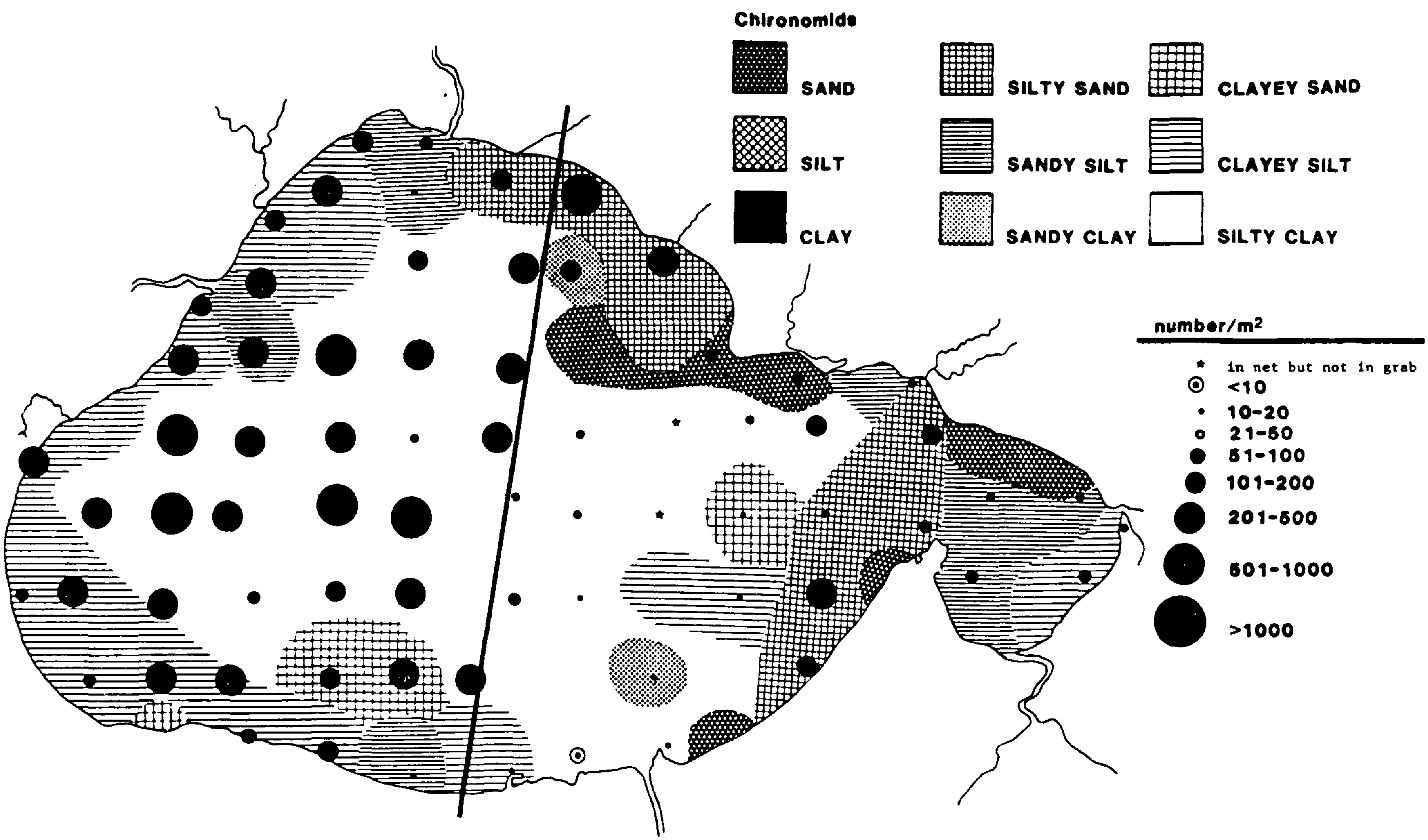
Appended Figure 10. Distribution of Nereis succinea in Lake Pontchartrain, LA, as determined during the present study.



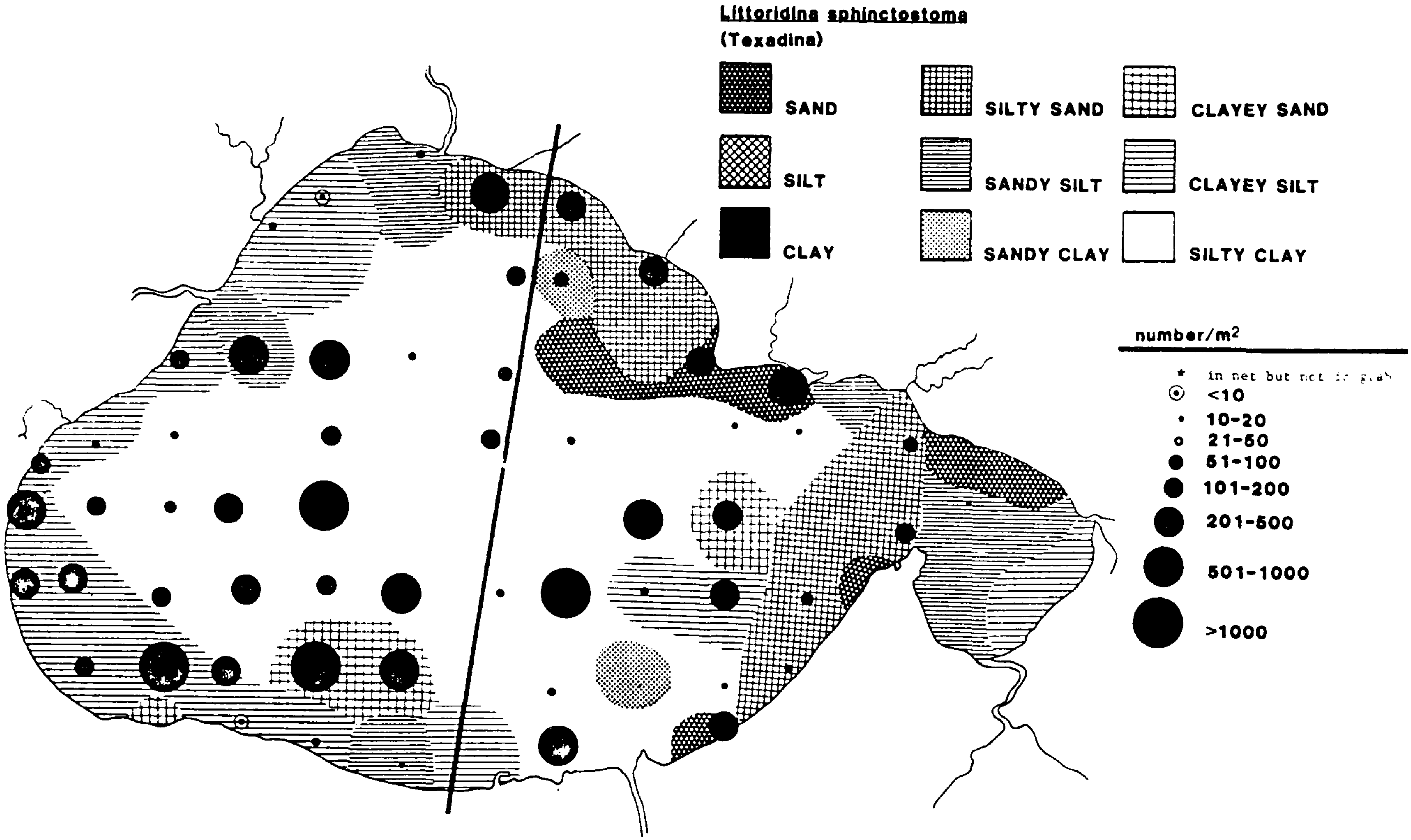
Appended Figure 11. Distribution of *Cyathura polita* in Lake Pontchartrain, LA, as determined during the present study.



Appended Figure 12. Distribution of Oligochaetes in Lake Pontchartrain, LA, as determined during the present study.



Appended Figure 13. Distribution of Chironomids in Lake Pontchartrain, LA, as determined during the present study.



Appended Figure 14. Distribution of Littoridina sphinctostoma in Lake Pontchartrain, LA, as determined during the present study.

Chapter 12

NEKTON OF LAKE PONTCHARTRAIN, LOUISIANA, AND ITS SURROUNDING WETLANDS

by

Bruce A. Thompson
and
J. Stephen Verret

ABSTRACT

The nekton of the Lake Pontchartrain estuary was studied from January through December 1978. Twelve lake and four marsh stations produced a total of 83,709 specimens, comprising 85 species in 39 families.

The five most abundant lake species were *Anchoa mitchilli*-bay anchovy, *Micropogonias undulatus*-Atlantic croaker, *Brevoortia patronus*-Gulf menhaden, *Menidia beryllina*-tidewater silverside, and *Syngnathus scovelli*-Gulf pipefish; these comprised 81.2% of the lake fauna. The five most abundant marsh species were *Cyprinodon variegatus*-sheepshead minnow, *Anchoa mitchilli*, *Poecilia latipinna*-sailfin molly, *Lucania parva*-rainwater killifish, and *Brevoortia patronus*, and they comprised 52.9% of the marsh fauna.

The community is marked by strong seasonal movements: primarily larval immigration in winter and spring and adult emigration in fall and winter. Seasonal faunal similarities in the lake were: winter-spring 44%, spring-summer 53%, and summer-fall 63%. Respective marsh values were 48%, 52%, and 60%.

Information theory diversity values seem to indicate a moderately healthy fish fauna. Overall diversity (H) ranged from 1.36 to 2.55 ($\bar{X}$ = 1.88) in the lake and from 1.69 to 2.90 ($\bar{X}$ = 2.22) in the marsh. Species richness (D) showed a fall maximum, reflecting an influx of temporary marine visitors to the community. These rare species lowered equitability (E) and evenness (J) values.

Lake Pontchartrain seems most important not as a spawning area, but rather as a feeding and nursery area for the young of many species in the southeastern Louisiana estuarine complex.

INTRODUCTION

Lake Pontchartrain is part of a large, complex, warm-to-temperate estuarine system that occupies much of southeastern Louisiana. Components of this system make up a series of water bodies that gradually change from limnetic (<0.5 °/₀₀) (Lakes Maurepas and Pontchartrain), to oligohaline (0.5 to 5.0 °/₀₀) and mesohaline (5.0 to 18.0 °/₀₀) (Lakes Pontchartrain and Borgne), ending in polyhaline (18 to 30 °/₀₀) (Breton, Chandeleur, and Mississippi Sounds) and euhaline waters (30 to 40 °/₀₀) (Gulf of Mexico) (Remane and Schlieper 1971, Gunter 1961).

Different aspects of the physical makeup of the area have been described in detail in several studies (Darnell 1958, 1962a; Tarver and Dugas 1973; Montz 1978). Darnell (1962a) and Saucier (1963) discussed the geological and ecological history of the lake. Gunter (1952, 1953) and Tarver (1974) presented historical information on interconnections between the Mississippi River and Lake Pontchartrain. Steinmayer (1939) described bottom sediments of Lake Pontchartrain.

Lake Pontchartrain is roughly oval in shape (being longer on its E-W axis) and occupies approximately 1632 sq km. It is shallow (maximum natural depth, 5 m) but relatively flat-bottomed; 75% of the area is 3 m or more in depth (Steinmayer 1939). Dredging by man and natural scouring near The Rigolets and the Chef Menteur Pass have produced depths of 6-33 m.

There have been few studies on fishes in Lake Pontchartrain. The earliest comprehensive study was conducted between 1953 and 1955 (Suttkus et al. 1953 a-c; 1954 a-f; 1955 a-b). This survey found 92 species of fish. In a limited two-year study, Davis et al. (1970) collected 39 species of fish but made no new records. Tarver and Savoie (1976) found four species new to the lake in their study that produced 65 species of fishes. Prior to the present study, 96 species of fishes were known from Lake Pontchartrain.

OBJECTIVES

During 1978, a year-long study of the fishes of the Lake Pontchartrain estuary was conducted to address seven main objectives: 1) to acquire an accurate picture of which fishes occupy the lake, 2) to update our knowledge on the abundance and distribution of the fishes, 3) to obtain an understanding of the importance of seasonality in the biology of the lake, 4) to find interrelationships between the lake and surrounding marsh area, 5) to evaluate the overall diversity of the fish community, 6) to determine the interconnection of Lake Pontchartrain with the other bodies of water in the complex estuarine system of southeastern Louisiana, and 7) to establish an information base upon which potential changes in the various components of the fish community in the lake can be assessed.

MATERIALS AND METHODS

I. Collecting Procedures

Fish were normally preserved in 10% unbuffered formalin for at least a week, then throughly rinsed one to several times with water, allowed to soak several more days in the water, and then transferred to 45% isopropanol for storage while processing. In certain instances, specimens were weighed and measured fresh in the field. This was true of certain large specimens or material where the alimentary tract was dissected out for food habits analysis. For most collections, at least 25 specimens of each species (if present) were individually weighed and measured. In addition, the total number and gross weight of each species were also recorded.

Data on each species were coded, and all pertinent data were then transferred to computer cards.

II. Sampling Gear and Problems

In an attempt to overcome the obvious collecting bias of many of the fish collecting methods, several types of gear were fished at a given location (where possible). It is hoped that this produced a more accurate picture of the seasonal successions and diversity of species in Lake Pontchartrain and surrounding marsh area. McHugh (1966) discussed the problems of adequately sampling seasonal successions and the varying niches of the estuarine community. He summarized these problems as:

> These successions can be followed only partially by considering the catches by any one kind of gear. Most estuarine species seek the deeper waters of the channel in winter, but spread out into the shallower littoral areas in spring and summer. Some may be demersal at certain times, pelagic at others. Many species are most active in spring and fall and relatively

inactive in midsummer and winter. Each change has a different effect on the availability of each species to each type of gear and in each part of the estuary. Thus, conclusions on relative abundance, distribution, and size and age composition of estuarine nekton must be derived from catches by various kinds of gear, integrated with a considerable amount of subjective interpretation and qualitative observation. Despite these sources of error, biologists who are experienced students of estuarine nekton are justifiably confident that their conclusions reflect the true patterns of distribution and abundance with reasonable accuracy.

Haedrich and Hall (1976) also outlined estuarine fish sampling problems and concluded that "for most sampling procedures, the sample is, at best, only semiquantitative." In 1975, de Sylva reported on the lack of realistic evaluations of the larger, swift-swimming fishes that can easily evade capture by most methods normally used in estuarine studies. In the present study in Lake Pontchartrain, such species would include bull shark (Carcharhinus leucas), tarpon (Megalops atlantica), needlefish (Strongylura marina), and jack (family Carangidae). Caution must be used in any evaluation of the importance of the ecological role of these species because they are probably underestimated. The following list describes gear used during the study.

A. SEINES: Three different seines were used when conditions permitted.

1) A 3 m, 4.3 mm mesh, straight seine. This was the standard seine used at the seining stations.
2) A 10.7 m, 12.7 mm mesh, bag seine. This was used where larger beach areas permitted use of a bigger seine.
3) A 45.7 m, 12.7 mm mesh, bag seine. This was used only where large, open beach areas existed (e.g., Station 4).

B. TRAWLS: Three different trawls (TR) were used.

1) A 4.9 m, 19.1 mm mesh trawl. This was the standard trawl used for most of the survey.

2) A 2.4 m, 19.1 mm mesh trawl. This was used only in the marsh where restricted trawling areas existed.

3) A 9.1 m, 19.1 mm mesh trawl. This was used for the first month in the open lake and then discontinued.

C. STATIONARY NETS (STNT): These were set at five stations (1, 4, 6, 8, and 10) around the lake. Two standard types were used, gill nets (G) and trammel nets (T); together they are referred to as stationary nets (STNT).

1) A 91.4 m, gill net, 1.8 m deep, made up of 4, 22.85 m sections, each a different mesh size, was the standard gill net. The mesh sizes (bar measurement) were 25.4 mm, 50.8 mm, 76.2 mm, and 101.6 mm and were set in random order in constructing the net. To avoid net damage, all sets were bottom sets.

2) A 91.4 m wide, 1.8 m deep, trammel net was used. The inner net mesh was 38.1 mm; the outer mesh was 254 mm. The trammel net was discontinued after four months when concentrations of blue crabs (Callinectes) made running the nets overly time consumming.

D. ELECTROSHOCKER (SHKR): An aluminum bateau with a gasoline-powered D.C. generator was used at certain areas of the marsh stations to supplement the regular collections in an attempt to overcome

some of the adverse conditions (such as soft, mud bottoms and snags) that made the normal techniques inadequate.

E. DIPNETS (D): A number of different dipnets of 4.8 mm and 6.4 mm mesh were used in the marsh and other dense grassbeds where other collecting techniques proved to be inefficient.

To standardize the collecting stations, time periods or given areas were used to provide a uniform basis. Where possible, two regimes were used, trawling and stationary nets.

Trawling speed was kept constant at 2000 rpm, and in the lake duration was 0.5 hr. Distance covered varied slightly with lake conditions but was measured against fixed markers (such as powerline towers) in the lake and on shore. These distances were checked against U.S. Coast and Geodedic Survey (USC&GS) map No. 11369 (Lakes Pontchartrain and Maurepas). Average distance trawled was 3200 m (∿2 miles). Wagner (1973) and Loesch et al. (1976) estimated their 4.9 m (16') trawl swept an area 2.5 m wide. Present observation resulted in an estimate of a 3.5 m (∿11.5 ft) wide trawling area. The bottom of Lake Pontchartrain is relatively clean and smooth and may allow the trawl to fish normally with a wider opening. Heavy vegetation growth at several marsh stations caused the trawl to become obstructed and to fish with a noticeable reduction in catch width. Multiplying distance trawled (3218 m) by opening width of the trawl (3.5 m) gives an average area swept in the lake of 11,263 m^2. This figure was used in calculating population density and biomass estimates.

Stationary nets were set for a standard period of 240 min. (4 hr).

When seining or electroshocking, an attempt was made, where possible, to cover nearly the same area each month at different stations. Changes

in water depth, heavy growth of plants, snags and many other obstacles made this technique at best a semiquantitative estimate as explained previously. The time interval for each shocking or seining station was also recorded to give an estimate of effort spent at each area.

Salinity and water temperature were determined from a YSI (Model 33) temperature-conductivity meter. Preliminary study showed little, if any, stratification, so surface readings were used. A Secchi disc was used for turbidity readings. A boat-mounted depth finder was used to determine water depths; these data were compared with USC&GS map 11369. Direct observations and the USC&GS map were used to determine bottom type. Field identification and preserved samples were made and compared with Montz (1977) for determination of aquatic plant samples. The order of scientific and common names of fishes listed follows Bailey et al. (1970) (except where more recent findings have changed the accepted names).

The median (Mdn) and the mean ($\bar{X}$) are given on several tables because inferences drawn from a sample median about the population median, although not as accurate as those drawn from a sample mean, are safer and more general in the sense that they do not rest on the assumption of normality.

Figure 1 shows the location of 17 nekton stations sampled during the present study. They were located at major tributaries and passes of the lake to monitor potential movements of the fish species. Four marsh stations were sampled to identify possible interrelationships between the lake and surrounding marsh. Both inshore and open water lake stations were set up to monitor two major ecological regimes.

III. Station Descriptions

A. Lake Stations

STATION ONE. Lake Pontchartrain, SW off mouth of Pass Manchac (30° 16.8' N; 90° 18.5' W). WATER DEPTH: 1-3 m. SALINITY: 0-2 ‰, $\bar{X}$ = 1.2 ‰. WATER TEMPERATURE: 7-30° C, $\bar{X}$ = 19.9° C. TURBIDITY: 5-125 cm, $\bar{X}$ = 55 cm. GEAR: G, T, TR. This was an open lake station with no observed vegetation. The bottom was hard mud (with many submerged tree stumps and logs), except for the Pass Manchac delta area, which was soft silt and mud.

STATION TWO. Lake Pontchartrain off mouth of Tangipahoa River (30° 20.3' N; 90° 16.2' W). WATER DEPTH: 0-3.3 m. SALINITY: 0-1.4 ‰, $\bar{X}$ = 0.6 ‰. WATER TEMPERATURE: 7-32° C, $\bar{X}$ = 20.6° C. TURBIDITY: 5-90 cm, $\bar{X}$ = 45 cm. GEAR = S, TR. This station included a seine collection at a shell and mud island and a trawl approximately 1 km ESE of the island, just outside a set of electric power lines. Submerged vegetation of the shore station included Cabomba, Ceratophyllum, Myriophyllum, and several filamentous green algae.

STATION THREE. Lake Pontchartrain off the mouth of the Tchefuncte River (30° 22.0' N, 90° 10.8' W). WATER DEPTH: 2-3.3 m. SALINITY: 0-2 ‰, $\bar{X}$ = 1.3 ‰. WATER TEMPERATURE: 6-32° C, $\bar{X}$ = 20.3° C. TURBIDITY: 3-135 cm, $\bar{X}$ = 87 cm. GEAR: T (a shore seining station was tried during January and February and then was discontinued for the remainder of the study). This was an open lake station with no observed vegetation. The bottom was mud mixed with patches of hard clay.

STATION FOUR. Lake Pontchartrain at Goose Point (30° 15.6' N; 89° 59.0' W). WATER DEPTH: 0-3 m. SALINITY: 0-3.8 °/₀₀, $\bar{X}$ = 2.2 °/₀₀. WATER TEMPERATURE: 6-31.5° C, $\bar{X}$ = 20.0° C. TURBIDITY: 5-165 cm, $\bar{X}$ = 74 cm. The maximum Secchi disc reading for the study (195 cm) was observed at this station on November 14, 1978. GEAR: G, T, S, TR, D. This station included both shore and open lake areas. There were large, dense, submerged grass beds along shore at this station. Dominant vegetation was Vallisneria, but large patches of Ceratophyllum, Myriophyllum, Cabomba, and Cladophera were present. The bottom ranged from sand (along the shore) to soft mud (offshore in open lake area).

STATION FIVE. Lake Pontchartrain between Big Point and South Point, usually 1 to 2 km W of Railroad Bridge (30° 11.0' N; 89° 53.5; W). WATER DEPTH: 2.75-3.3 m. SALINITY: 1.8-5.1 °/₀₀, $\bar{X}$ = 3.4 ppt. WATER TEMPERATURE: 5-29.5° C, $\bar{X}$ = 19.5° C. TURBIDITY: 2-110 cm, $\bar{X}$ = 72 cm. This was an open lake station with no observed vegetation. Small fragments of the hydroid Garveia franciscana were rarely taken. Crowell and Darnell (1955) listed this species (Bimeria franciscana) as abundant in this area. The bottom was soft mud.

STATION SIX. Lake Pontchartrain at The Rigolets (30° 10.7' N; 89° 44.8' W). WATER DEPTH: 0-6 m. SALINITY: 1.9-8.5 °/₀₀, $\bar{X}$ = 3.7 °/₀₀. Maximum salinity measured during the normal nekton sampling (8.5 °/₀₀) was observed at this station on November 15, 1978. WATER TEMPERATURE: 5-30° C, $\bar{X}$ = 19.7° C. TURBIDITY: 10-100 cm, $\bar{X}$ = 64 cm. GEAR: G, T, S, TR, D. This station included both shore (north shore of The Rigolets, W of Hwy. 90) and open lake areas. There were fairly large inshore grassbeds of Vallisneria and Ruppia as well as several unidentified

filamentous algae. In the open lake areas, Garveia franciscana, a hydroid, was fairly abundant during certain fall months. The bottom was a mixture of hard and soft mud, with areas of sand along shore.

STATION SEVEN. Lake Pontchartrain at mouth of Chef Menteur Pass (30° 05.9' N; 89° 49.2' W). WATER DEPTH: 1-6m. SALINITY: 1.8-6.8 °/oo, $\bar{X}$ = 4.3 °/oo. WATER TEMPERATURE: 5-30° C, $\bar{X}$ = 20.0° C. TURBIDITY: 12-100 cm, $\bar{X}$ = 64 cm. GEAR: TR. This was an open lake station (the first few months were done in the lake and Chef Menteur Pass, but this was discontinued) that had no observed vegetation. Hydroid was collected similarly to Station Six. The bottom was soft mud.

STATION EIGHT. Lake Pontchartrain W of mouth of Inner Harbor Navigation Canal (IHNC) (30° 02.4' N; 90° 02.4' W). WATER DEPTH: 0-7.3 m. SALINITY: .5-5.5 °/oo, $\bar{X}$ = 3.3 °/oo. WATER TEMPERATURE: 8-30.5° C, $\bar{X}$ = 20.9° C. TURBIDITY: 10-160 cm, $\bar{X}$ = 78 cm. GEAR: G, T, S, TR. This station included both shore and open lake areas. The seining area was located at the Seabrook Bridge boat ramp area behind breakwaters. It included both a sand beach and boat ramp. The concrete ramp had large patches of Enteromorpha growing on it during warm weather. The open lake stations had no observed vegetation and a mud bottom. The trawl station started near the channel at the mouth of the IHNC and ran west a short distance off the south shore seawall.

STATION NINE: Lake Pontchartrain approximately 1.5 km W of Causeway and 1.5 km off south shore (30° 02.2' N; 90" 10.0' W). WATER DEPTH: 3.3-4.2 m. SALINITY: .5-3.9 °/oo, $\bar{X}$ = 2.6 °/oo. WATER TEMPERATURE: 7-30° C, $\bar{X}$ = 20.4. TURBIDITY: 10-150 cm, $\bar{X}$ = 72 cm. GEAR: TR. This was an open lake station with no observed vegetation. The bottom was soft mud.

STATION TEN. Lake Pontchartrain off the mouth of Bayou La Branche (30° 04.3' N; 90° 21.0' W). WATER DEPTH: 0-2.5 m. SALINITY: 0-3 $^{\circ}/_{oo}$, $\bar{X}$ = 1.9 $^{\circ}/_{oo}$. WATER TEMPERATURE: 7-29.5° C, X = 20.7° C. TURBIDITY: 5-140 cm, $\bar{X}$ = 62 cm. GEAR: G, T, S, TR. This station included a seining area at a large shell, sand, and mud beach just east of the mouth of Bayou LaBranche. The open lake area was along the power lines located about 1.5 km offshore. The surface of the lake was often covered with large patches of *Lemna* (duckweed) blown into the lake from nearby swamps and marshes. The bottom of the entire area was a mixture of mud, silt, and sand. There were large concentrations of *Rangia* shells near shore and in adjacent shallow water. The inshore area was dotted with many sunken logs and stumps (mostly *Taxodium*, cypress).

STATION ELEVEN. Lake Pontchartrain along west shore powerlines (between towers 130 and 140), about 8 km ESE of Ruddock (30° 11.8'N; 90° 21.0' W). WATER DEPTH: 3.0-3.3 m. SALINITY: .5-2.8 $^{\circ}/_{oo}$, $\bar{X}$ = 2.0 $^{\circ}/_{oo}$. WATER TEMPERATURE: 11-32° C, $\bar{X}$ = 21.3° C. TURBIDITY: 20-100 cm, $\bar{X}$ = 50 cm. GEAR: TR. This was an open lake station with a relatively soft mud bottom. During several of the summer months the surface was covered with blue-green algae (some samples identified as *Anabaena*).

STATION TWELVE. Lake Pontchartrain at center of lake running parallel near the Causeway, usually starting or ending near Causeway mile marker 12 (30° 11.3'; 90" 07.2' W). WATER DEPTH: 4.2-4.6 m. SALINITY: 1.8-4.5 $^{\circ}/_{oo}$, $\bar{X}$ = 2.9 $^{\circ}/_{oo}$. WATER TEMPERATURE: 5-30° C, $\bar{X}$ = 20.0° C. TURBIDITY: 2-100 cm, $\bar{X}$ = 63 cm. GEAR: TR. This was an open lake station with no observed vegetation. The bottom was soft mud with a mixture of *Rangia* shells.

B. Marsh Stations

STATION THIRTEEN. Chef Menteur Pass marsh area near mouth of Bayou Sauvage (30° 0.4' N; 89° 48.7' W). WATER DEPTH: 0-1.8m. SALINITY: 1-6.7 ‰, $\bar{X}$ = 4.2 ‰. WATER TEMPERATURE: 7.8-32°C, $\bar{X}$ = 21.6° C. TURBIDITY: 2-100 cm, $\bar{X}$ = 46 cm. GEAR: S, TR, D. This marsh area was sampled in three different habitats: a large open pond, a large tidal stream, and a small side tributary of the tidal stream. The bottom in all areas was soft mud, except for the deepest center of the tidal stream where it was harder mud with some clay. During the warm months, most of the aquatic area of the marsh had dense growths of Vallisneria and Ceratophyllum. The depths in the sampling areas changed nearly .6 m with the tide and wind. At low water levels, most of the small tributaries would be nearly dry; at flood, the entire marsh area would be covered with water.

STATION FOURTEEN. Walker Canal between Lake Pontchartrain and I-10 (30° 01.6' N; 90° 18.8' W). WATER DEPTH: 0-2.4 m. SALINITY: 0-3 ‰, $\bar{X}$ = 1.7 ‰, WATER TEMPERATURE: 9-31° C, $\bar{X}$ = 21.8° C. TURBIDITY: 12.5-42.5 cm, $\bar{X}$ = 28 cm. GEAR: G, T, S, TR, D, SHKR. This station included the main marsh canal and a small side tributary. The bottom was soft mud mixed with peat. The canal water was consistantly stained a dark brown from dissolved marsh components. During the warm months, the main canal contained heavy growths of Ceratophyllum, Myriophyllum, and Cabomba. The water changed greatly with changes in wind. The small side tributary would often have little or no water except where it connected with the main canal. These conditions were generally brought on by a strong southerly wind.

STATION FIFTEEN. T (or Tee) Bayou, North Pass, and adjacent marsh area about 1.5 km E of Pass Manchac (30° 18.5' N; 90° 2.3.3' W). WATER DEPTH: 0-1.8 m. SALINITY: 0-1.6 °/₀₀, $\bar{X}$ = .8 °/₀₀. WATER TEMPERATURE: 6-30° C, $\bar{X}$ = 21.2° C. TURBIDITY: 10-80 cm, $\bar{X}$ = 39 cm. GEAR: S, TR, D, SHKR. The dominant aquatic vegetation was *Alternanthera* (alligator-weed), *Utricularia* (bladderwort), and *Najas*. The bottom was soft mud. The water level changed greatly at this station, leaving isolated pools in the marsh at low levels. These were sampled to evaluate the more permanent marsh inhabitants.

STATION SIXTEEN. Bayou LaCombe and small marsh tributaries about 1.5 km inland from the north shore of Lake Pontchartrain (30° 16.8' N; 80° 57.3' W). WATER DEPTH: 0-2.1 m. SALINITY: 0-2.8 °/₀₀, $\bar{X}$ = .8 °/₀₀. WATER TEMPERATURE: 5-30° C, $\bar{X}$ = 19.4° C. TURBIDITY: 15-100 cm, $\bar{X}$ = 56 cm. GEAR: S, TR, D, SHKR. The main bayou was sampled with trawl and shocker; the small tributary was worked with seines and dipnets. Both the main bayou and tributary had heavy growths of *Cabomba*, *Myriophyllum*, *Ceratophyllum*, *Vallisnaria*, and filamentous green algae during the warmer months. The bottom in most areas was very soft mud. In several areas along a shell road there were firmer substrates where shell had spilled into the water.

STATION SEVENTEEN. Lake Pontchartrain at mouth of Bayou St. John near Lakeshore Drive bridge (30° 05.0' N; 90° 01.6' W). WATER DEPTH: 0-1.8 m. (Note: This station was not sampled from 1/78 to 5/78). SALINITY: 3.1-4.8 °/₀₀, $\bar{X}$ = 4.0 °/₀₀. WATER TEMPERATURE: 12-30.2° C, $\bar{X}$ = 25.2° C. TURBIDITY: 55-150 cm, $\bar{X}$ = 108 cm. GEAR: S, SHKR. This station

STATION FIFTEEN. T (or Tee) Bayou, North Pass, and adjacent marsh area about 1.5 km E of Pass Manchac (30° 18.5' N; 90° 2.3.3' W). WATER DEPTH: 0-1.8 m. SALINITY: 0-1.6 ‰, $\bar{X}$ = .8 ‰. WATER TEMPERATURE: 6-30° C, $\bar{X}$ = 21.2° C. TURBIDITY: 10-80 cm, $\bar{X}$ = 39 cm. GEAR: S, TR, D, SHKR. The dominant aquatic vegetation was *Alternanthera* (alligator-weed), *Utricularia* (bladderwort), and *Najas*. The bottom was soft mud. The water level changed greatly at this station, leaving isolated pools in the marsh at low levels. These were sampled to evaluate the more permanent marsh inhabitants.

STATION SIXTEEN. Bayou LaCombe and small marsh tributaries about 1.5 km inland from the north shore of Lake Pontchartrain (30° 16.8' N; 80° 57.3' W). WATER DEPTH: 0-2.1 m. SALINITY: 0-2.8 ‰, $\bar{X}$ = .8 ‰. WATER TEMPERATURE: 5-30° C, $\bar{X}$ = 19.4° C. TURBIDITY: 15-100 cm, $\bar{X}$ = 56 cm. GEAR: S, TR, D, SHKR. The main bayou was sampled with trawl and shocker; the small tributary was worked with seines and dipnets. Both the main bayou and tributary had heavy growths of *Cabomba*, *Myriophyllum*, *Ceratophyllum*, *Vallisnaria*, and filamentous green algae during the warmer months. The bottom in most areas was very soft mud. In several areas along a shell road there were firmer substrates where shell had spilled into the water.

STATION SEVENTEEN. Lake Pontchartrain at mouth of Bayou St. John near Lakeshore Drive bridge (30° 05.0' N; 90° 01.6' W). WATER DEPTH: 0-1.8 m (Note: This station was not sampled from 1/78 to 5/78). SALINITY: 3.1-4.8 ‰, $\bar{X}$ = 4.0 ‰. WATER TEMPERATURE: 12-30.2° C, $\bar{X}$ = 25.2° C TURBIDITY: 55-150 cm, $\bar{X}$ = 108 cm. GEAR: S, SHKR. This station

was a large, firm sand and silt delta that extended into the lake north of the Lakeshore Drive bridge. South of the bridge and protected by it was a large, dense bed of vegetation. This growth included Vallisneria, Ruppia, Ceratophyllum, and Cladophora (a filamentous green algae). This was the largest area of vegetation found on the south side of Lake Pontchartrain during the survey.

RESULTS

I. Physical Description of Lake

Table 1 and Figure 2 show the station and monthly average salinity for Lake Pontchartrain. Table 2 presents a classification of stations using the Venice System as shown in Remane and Schlieper (1971). In 1978, the lake salinity ranged from 0 to 8.5 $^{\circ}/_{\circ\circ}$. The salinity pattern was similar to that described by Darnell (1958) with western stations having lower salinities and eastern stations being higher in salinity. Five lake and three marsh stations had a minimum of 0 $^{\circ}/_{\circ\circ}$; The Rigolets station (No. 6) showed a maximum of 8.5 $^{\circ}/_{\circ\circ}$. The lake minimum occurred in January (1.0 $^{\circ}/_{\circ\circ}$) and slowly increased during the year to a maximum in November (3.8 $^{\circ}/_{\circ\circ}$), with a subsequent drop in December. The lake average for the year was 2.6 $^{\circ}/_{\circ\circ}$. The range and monthly averages compare in value with those presented in Table 3 from previous Lake Pontchartrain studies.

Table 4 presents water temperatures for the lake during 1978. Figure 3 shows a close correlation between air and lake temperatures. Table 5 gives rainfall and air temperatures for the southeastern section of Louisiana area influencing Lake Pontchartrain. The average minimum lake temperature (6.2° C) occurred in January and maximum average (30.0° C),

in July. Average temperature for the year was 20.7° C. The lake warmed slowly between January and March and then rapidly between March and April. Between April and June there was a continued slow increase. There was a relatively uniform maximum of 28 to 32° C between June and August. The fall decrease was not as steep as the spring increase. Maximum decline was between September and October and November and December. Presumably an additional decline occurs between December and January, but the sampling period was not continued into 1979. Suttkus et al. (1954d) noted a very similar water temperature pattern in the lake.

Table 6 and Figure 2 show the turbidity of Lake Pontchartrain for 1978. The turbidity pattern roughly follows that of salinity. The lake maximum (7 cm; note: the smaller the Secchi disc reading, the greater the turbidity and, inversely, the lower the water transparency) occurred in January. There was decreased turbidity in February and it was followed by a slight increase in March. Between March and June there was close to a fourfold increase in the clarity of the lake water. During the summer and fall months there was an irregular pattern of increases and decreases in water clarity, but in general there was an upward trend. The minimum monthly average (109 cm) in lake turbidity occurred in November 1978 and was followed by a noticeable increase in December. The major factors that seem to influence lake turbidity are direction and strength of wind. Winter-spring maximum turbidity coincides with stronger winds during those periods.

II. Lake Pontchartrain Fishes

A. Composition, Distribution, and Abundance

A total of 83,709 individuals (62,611 lake specimens, 21,098 marsh specimens) comprising 85 species and 39 families was collected in 1978 (Tables 7-9). Table 10 lists those species previously reported from the lake but not collected in the present study. The additional 32 species give a theoretical total of 117 species from 51 families constituting the Lake Pontchartrain (including marsh) fish fauna.

Table 11 lists the most abundant species collected each month and presents a total summary for the year. *Anchoa mitchilli* was the most abundant species taken in Lake Pontchartrain, with 22,067 specimens collected in 1978. Due to its importance in Lake Pontchartrain, *Anchoa mitchilli* 's discussed in greater detail in a separate report (Verret, Chapter 13). *Micropogonias undulatus*, *Brevoortia patronus*, *Menidia beryllina*, *Syngnathus scovelli*, and *Arius felis* were other species taken very abundantly ($\sim 10^3$) in the lake during 1978. The present survey found the top 10 species comprised 90.5% of the individuals.

The monthly distribution of the 20 most abundant species of the lake and marsh are shown in Figures A16-A35 (See Appendix I). None of the species found in the Lake Pontchartrain estuary can be considered a year-round ubiquitous (found in all habitats) species; however, 27 species (36%) were taken during all four seasons (Table 12). Table 13 classifies the 20 most abundant species by their primary and secondary habitats. Major changes in both distribution and abundance in Lake Pontchartrain result from recruitment of young (and sometimes spawning adults) into the lake. Dominant species that have this pattern are:

Anchoa mitchilli, *Micropogonias undulatus*, *Brevoortia patronus*, *Leiostomus xanthurus*, *Arius felis*, *Mugil cephalus*, *Cynoscion arenarius*, and *Cynoscion nebulosus*.

For some species, the juveniles move into the lake to occupy a different habitat than the adults. Two important species that change habitat with age are *Brevoortia patronus* and *Cynoscion nebulosus*. The young *Brevoortia* move into the lake during April and May in large schools and are very abundant ($>10^3$) in the inshore beach areas of the lake and the marsh canals. They grow quickly, and by June they have moved from this inshore habitat to open waters of the lake. Young-of-the-year *Cynoscion nebulosus* move into the lake between June and September and are found exclusively in the grassbeds along the shores of the lake. They do not occupy these same grassbeds in the nearby marsh. They inhabit these beds throughout summer and fall and move into the more open parts of the lake. Whether they overwinter in the lake or migrate into higher salinity waters cannot be determined from our present survey information.

Table 14 gives the numbers of species (S) collected by trawl. Trawl collections are probably reasonably consistent in terms of efforts and show moderate uniformity in this component of the fish community. Coefficient of variation (CV) for the 12 stations (in a given month) are the lowest found for biological parameters measured in the present study (see Tables 18 and 19 for comparison). Table 15 presents an index of occurrence for the 20 most abundant species in the Lake Pontchartrain estuary. As the various species move into and out of the area, they are caught with greater or lesser frequency. *Anchoa mitchilli*, *Micropogonias*

undulatus, and Brevoortia patronus, at the peak of their abundance, were captured at all or nearly all of the sampling stations. Two species, Leiostomus xanthurus and Arius felis, seem to be totally absent from the lake for three to five of the colder months before they move into the lake and become quite common ($>10^2$).

Table 16 presents monthly catch results for Lake Pontchartrain for 1978. Different sampling methods operate on entirely dissimilar collecting principles and thus are listed separately in monthly totals. Figures 4-7 show catch-effort (CE) values for both total numbers and species (S) for the different gear types. For most of the stations there are irregular patterns, and maximum CE values do not correspond with maximum S figures. The maximum number of species collected by seine was 24 (Sta. 4, July; Sta. 6, November); by trawl, 10 (Sta. 4, September); by stationary net, 12 (Sta. 4, April). The maximum CE value (fish/hr) for seining was 4700 (Sta. 10, April); for trawling, 2100 (Sta. 9, September); and for stationary net, 25 (Sta. 4, April).

Table 17 presents similar but more irregular patterns for the marsh area. As discussed previously, the water level in the marsh fluctuates greatly with wind and tidal influences. These changes in level probably lead to widely varying CE results because the flooded marsh permits fishes to disperse to where they are nearly inaccessible. The maximum number of species for the four marsh stations was 16 (Oct.), 14 (Dec.), 8 (Jan. and April), and 8 (Feb.) by trawl; 13 (Dec.), 14 (June), 7 (March), and 13 (Oct. and Nov.) by seine. The electroshocker proved very effective in the marsh and produced an average of 13 species in 6 samples.

Figure 8 shows a comparison of mean monthly CE for the lake and surrounding marsh area.

Table 18 and Figure 9 presents population estimates (fish/m^2) for demersal fish from the 12 trawling stations. Values ranged from 0 (Sta. 11, June) to .093 (Sta. 9, Sept.). The highest monthly average (.036) occurred in July, and Station 9 had the greatest yearly average (.029). The southwest region of the lake (Sta. 9, 10, and 11) had the highest yearly averages. Station 8 (near the IHNC) had the lowest yearly average. January had the lowest average; February through April values were also low. The high Coefficient of Variation (CV) values probably reflect the overall "non-homogeneous" nature of many fish populations.

Table 19 presents biomass estimates (gm/m^2) for the demersal fish similar to that in Table 18. Again, non-homogeneous distributions result in irregular biomass patterns and very high Coefficient of Variations ranging from 76.7 to 246.2 among stations on a monthly basis and 96.0 to 234.8 for given stations throughout the year. Non-normal distributions, skewed or bimodal, result in means 2 to 10 times larger than the median values. During December, the collection of 90 large <u>Ictalurus</u> <u>furcatus</u> at Stations 1, 2, and 11 resulted in biomass values considerably larger than normally found in the lake.

July and August had the highest median biomass values. On a yearly basis the station rank (by median) was as follows: 5, 9, 7, 11, 4, 6, 8, 2, 3, 10, 12, and 1. The pattern seems quite irregular, and no region of the lake was consistently high or low in biomass as determined from the trawling data.

In an attempt to compare biomass values from trawling with an entirely different type of gear, limited collecting during July and

August was done with a drop net (36 m^2). Biomass values ranged from .99 to 2.66 gm/m^2. These are higher than the corresponding monthly trawl values but over all are within the range obtained by trawling.

B. Seasonality

Probably the most important factors in the overall biology of the lake fishes are the cyclic changes in salinity, water temperature, turbidity, and submerged vegetation associated with the change in seasons. Although there may be years that have abnormal seasons, 1978 was divided into typical seasons: winter-December, January, February; spring - March, April, May; summer - June, July, August; fall - September, October, and November. Physically, each season can be characterized as follows:

1) Winter - low salinity, low water temperature, high turbidity, low or absent submerged plant growth, high winds, and high waves.

2) Spring - increases in salinity and water temperature, decreasing turbidity, onset of renewed plant growth, relatively decreased winds and waves.

3) Summer - increased salinity, maximum water temperature, continued decrease in turbidity, maximum submerged plant growth, low winds, and calm waters.

4) Fall - maximum salinity, decreased water temperatures, minimum turbidity, reduction or slowdown in plant growth, increase in winds and waves.

In addition, the overall photoperiod follows the same pattern as water temperatures.

These physical characteristics influence activities of the fishes. Table 20 presents salinity ranges for the most abundant fishes in the lake. Overall, as salinity of the lake increases, the maximum tolerance also increases since so that the maximum of many species is the maximum found in the lake. However, many species of fishes in Lake Pontchartrain do have tolerances greater than that found in the lake. Table 21 provides a provisional salinity classification that can present guidelines for the influence of salinity on the fish fauna of the lake. Overall the influence of salinity on fishes is more complex than the usual categories of "freshwater, estuarine, or marine." These groups grade from one to another.

Table 22 shows similar tolerance ranges for water temperature of the most abundant fishes in the lake. Overall, the average water temperature ranges of most of the species are near the yearly average of the lake. Certain species prefer colder water (Ictalurus furcatus and Mugil cephalus), and the yearly means are lower. Species such as Leiostomus xanthurus and Aruis felis do not enter the lake until it has warmed, and their yearly mean temperature is noticeably higher.

Table 23 presents turbidity ranges of the most abundant fish species. Most of those species that are found in the lake year round tolerate the high winter turbidities. As Darnell (1962a) pointed out, the fauna of Lake Pontchartrain has had a long geologic period of evolutionary adjustment to become acclimated to naturally turbid lake waters. Those species that are absent from the lake during the colder months (as previously discussed) are not found in the most turbid waters. Species such as Syngnathus scovelli that are found nearly exclusively in the grassbeds are also found in lower turbidity.

Figures 10 and 11 show the seasonal trends in the number of species (S) and specimens (N) in both the lake and marsh. The species number (S) trend follows closely that of the overall lake salinity, with the maximum number (Table 7) being found in November.

The seasonal trend in number of specimens (N) increases dramatically in the spring, reaches a peak in July, and gradually decreases in late summer and fall. This increase can be attributed to heavy recruitment in most of the dominant species, as discussed previously. Seasonal patterns of catch effort (CE) (Fig. 8) demonstrate the movements of certain species as they move into the lake during spring. The tremendous peak in CE for lake seining in April is due almost entirely to vast schools of Brevoortia patronus that have recently moved through the passes into the lake. As the CE values for seining fall off, the trawl values increase and reflect the addition of large numbers of Anchoa mitchilli, Micropogonias undulatus, Leiostomus xanthurus, Arius felis, and Cynoscion arenarius into open waters of the lake.

The trend for the number of species (S) is not as dramatic as that of N and generally rises slowly throughout the year and reaches a maximum in November.

Table 12 shows seasonal faunal similarities of the lake and marsh. The highest similarity percentage is found in the groups that occupy the lake during the summer and fall (63%). These two seasons also have the largest number of species (17) found in the lake only during the period. This component is a warm water, marine group that leaves the lake quickly when temperatures and salinity drop. Other major seasonal patterns are (Table 24: "summer only" - 6, "fall only" - 7, "winter-spring only" - , and "winter-spring-summer" - 4). Of the 15 potential seasonal

combination patterns, the only group missing from the lake were "winter only" species. This is not surprising since cold water species move in during late fall and continue through spring.

Figure 12 shows that two groups of fish that become more abundant in summer and fall with increased lake salinities are marine (group D) and freshwater species that possess higher salinity tolerences (group B2). Marine species comprise a group that dominates the lake community, and the seasonal population changes of these fishes are responsible for major increases and decreases in relative fish abundance.

Tables 24 and 25 list abundance patterns of the lake and marsh fish by season and give the dominant season (by percent and number) of each species. Three species, Menidia beryllina, Archosargus probatocephalus, and Pogonias cromis, are found in relatively equal abundance in all four seasons. Three primary marsh residents also had no particular dominant season. These were Poecilia latipinna, Lepomis microlophus, and L. punctatus.

C. Lake-Marsh Interrelationship

Much of Lake Pontchartrain is surrounded by marsh. Chabreck et al. (1968) listed three major types immediately adjacent to the lake: fresh, intermediate, and brackish marshes. Four nekton stations (Fig. 1) were set up in different areas of the marsh to obtain information on the possible interplay between the lake and its adjoining marsh. Stations 15 and 16, to the west and north of the lake, were set up in fresh marsh (Table 1). Station 14, in the St. Charles marsh area near the southwest corner of the lake, was intermediate in salinity (yearly $\bar{X}$ = 1.7°/₀₀) between Stations 15 and 16 and was the most saline station in

the Chef Menteur Pass marsh. Station 13 had a yearly average of 4.2 °/₀₀, nearly equal to the highest lake station (Sta. 7, $\bar{X}$ = 4.3°/₀₀) nearby at the mouth of Chef Menteur Pass.

Water temperatures for the four marsh stations (Table 4) were very similar, with Station 16 averaging slightly cooler from the influence of the flowing Bayou LaCombe water.

Marsh turbidity (Table 6) varied greatly from station to station and month to month. Tides and wind changed marsh levels up to .6 m at times and were a major influence on turbidity. Station 14 was the most turbid, averaging only 28 cm. Station 15 averaged 39 cm and Station 13, 46 cm. Station 16, again probably due to influence of the flowing Bayou LaCombe waters, was the clearest station and averaged 56 cm.

Table 7 lists the number of specimens and species collected each month from the marsh stations. The four stations produced a monthly average of 29 species and a total of 58 for the year. The maximum was 36 (October) and the minimum was 21 (May). Table 9 lists the individual species and the numbers collected each month in the marsh. Ten species were collected only in the marsh during the study. These were *Amia calva*, *Cyprinus carpio*, *Ictalurus natalis*, *Fundulus jenkinsi*, *Labidesthes sicculus*, *Morone chrysops*, *Centrarchus macropterus*, *Lepomis megalotis*, *Pomoxis nigromaculatus*, and *Microgobius thalassinus*. This group has both freshwater and euryhaline affintities (Table 21).

Table 26 presents a comparison of the fish fauna of the lake and surrounding marsh. Using a criterion of 66-67% (2/3 of the total specimens collected) occurrence, the 85 species can be grouped as 55 lake species, 22 marsh species, and 8 that have affinities with both

areas. Of the 55 lake species, 27 were collected only in the lake (species with * in Table 8), and 10 (previously listed) of the 22 species were collected only in the marsh. The 8 species collected roughly in equal abundance in both areas were: Lepisosteus spatula, Elops saurus, Ictalurus furcatus, Cyprinodon variegatus, Fundulus chrysotus, Fundulus grandis, Morone mississippiensis, and Micropterus salmoides.

Table 13 shows that for the 20 most abundant species in the estuary, 8 are primary marsh dwellers. These were (in order of their abundance): Cyprinodon variegatus, Lucania parva, Poecilia latipinna, Gambusia affinis, Lepomis punctatus, Lepomis macrochirus, Lepomis microlophus, and Heterandria formosa. In addition, several of the most important species such as Anchoa mitchilli, Brevoortia patronus, and Menidia beryllina make some use of the marsh during phases of their life cycle (secondary habitat).

The seasonal faunal similarity patterns (Table 12) in the marsh are very much like these of the lake. Twenty-six species are found in the marsh during all four seasons, compared with 27 for the lake; many of these species are the same in both the marsh and the lake (Tables 24 and 25).

D. Community Diversity

The concept of diversity based on ideas derived from information theory has proved most valuable in assessing biological communities. Recent reviews and discussion on theory and application to ecology have been given by Pielou (1975), Hutchinson (1978), and Krebs (1978) among others.

Margalef (1968), McErlean and Mihursky (1969), Dahlberg and Odum (1970), Bechtel and Copeland (1970), McErlean et al. (1973), Haedrich and Haedrich (1974), Haedrich (1975), Moore (1978), and others have shown the usefulness of applying these concepts to the study of fish communities.

In this study, four diversity indices were calculated. The Shannon-Weaver (Shannon and Weaver 1949) function is:

$$H = -\sum Pi \log_2 Pi \qquad (1)$$

where Pi is the proportion of individuals of the i-th species. This formula has been used widely in ecology as a species diversity index as discussed by Margalef (1957), Pielou (1975), and others. This index is sensitive to both the number of species and the proportional makeup of each species.

The "species richness" component of diversity was calculated by:

$$D = (S-1)/\log_2 N \qquad (2)$$

where S is number of species and N is number of individuals of each species.

Relative species abundance was measured by two indices. Lloyd and Ghelardi (1964) calculated a table for finding a theoretical number of species in a given environment based on the concepts of MacArthur (1957). This function of "equitability" is:

$$E = S'/S \qquad (3)$$

where S is the number of species and S' is the theoretical number calculated from Lloyd and Ghelardi's (1964) table.

Pielou's (1966, 1975) "evenness" index was also used:

$$J = H/\log_2 S \tag{4}$$

where H is the calculated diversity index from function (1), and the denominator is the log of the number of species. Functions (3) and (4) measure the same trends in the community, but (4) will be higher than (3), as discussed by Lloyd and Ghelardi (1964), because an environment in reality never has all its species uniformly proportioned or distributed.

All calculations of these functions in this report are based on $\log_2$ units. For comparison with other studies for values using natural logs ($\log_e$), conversion is:

$$\log_e X = .6931 (\log_2 X) \tag{5}$$

Table 27 and Figures 13-15 present monthly values of four diversity functions for the fish community in Lake Pontchartrain and surrounding marsh area.

Table 28 shows these same four functions with samples grouped by seasons instead of monthly.

The overall yearly diversity (H) pattern (Figure 13) for the marsh and lake were similar except for a higher early spring peak in the marsh and a late fall maximum. There was a decline in the lake from January to May followed by peaks in June and August. Diversity decreased to November, then increased sharply in December. The seasonality of H is well developed (Table 28) in the lake but fairly uniform in the marsh. The highest values occurred in the winter and summer and the lowest

during spring and fall. This agrees with the concept that spring and fall are periods of the greatest change in an estuary whereas summer and winter are seasons of more stability.

The species richness index (D) is sensitive to the movement of species into or out of the total community. It should show trends of migrations into the lake through the passes. The D values were low in the lake from January to May but increased sharply in June and eventually reached a maximum in November. There was a decrease in December that nearly returned to the low values of the previous January. This pattern reflects a trend of the total number of species (S) in the lake (Figure 10). The seasonality of D is also well developed (Table 28) in both the lake and marsh, with the lake values being higher throughout. Values decreased from winter to spring and then increased in summer. In the lake there was an additional sharp increase in fall, but in the marsh, the fall value was lower.

The trends in both equitability (E) and evenness (J) are similar, so only the equitability component will be discussed for reasons given by Lloyd and Ghelardi (1964). The measurement of this component of diversity permits an evaluation of the loss or gain of migratory species at different seasons that results in "seasonally compensating" (Dahlberg and Odum 1970) values of H. Equitability relates diversity of the community to its potential maximum. The values for E in the lake decreased from January to May. Following an increase in June, there was a gradual decrease to a yearly low in November with a dramatic increase in December. The equitability pattern for Lake Pontchartrain in 1978 was similar to that for diversity (H) and roughly the inverse of the species richness component (D). This pattern is generally the result of the influx of

Anchoa mitchilli, Micropogonias undulatus, Brevoortia patronus, Leiostomus xanthurus, Arius felis, and Cynoscion arenarius that made up nearly 75% of the lake fish fauna by numbers (Table 11). In addition, there were numerous rare migrants that moved into the lake with the increase in salinity that pushed the E values in November quite low. By late fall, there were a few dominant species and many rare species occupying the lake.

The equitability pattern of the marsh is quite irregular and more difficult to explain. The marsh values of E fluctuated widely from month to month. There were noticeably higher peaks in March and October. Possibly the main factor in the marsh affecting its equitability is the drastic changes in water level that are influenced by tides and strong winds. High water levels would permit some of the more common species to disperse out into the marsh flats, thereby making the community abundance more "even." Lowered water levels would force all the fish into the smaller tidal ditches, which would create tremendous concentrations of the common species and would lower E values. The importance of the changing water levels in the marshes to the health of these fish populations needs to be investigated in more detail than was possible during this study.

III. Invertebrates

Data on invertebrates are very inconclusive and potentially misleading. Adult brown shrimp, Penaeus aztecus, were taken in small numbers (56) between May and August. They were collected irregularly at most of the lake trawl stations. A few night seining collections were made at Goose Point (Sta. 4) and The Rigolets (Sta. 6) that contained

juvenile brown shrimp and point to the potential importance of submerged grass beds as a nursery area for this species. Tarver and Savoie (1976) noted that juvenile brown shrimp "only frequented the shallow water near the shore", and Gunter (1961) noted the early portion of its life cycle in low salinity inland waters. Tarver and Savoie (1976) discussed the potential importance of allowing the existing shallow-water sloping shoreline areas to remain unaltered for completion of the brown shrimp life cycle.

Adult white shrimp, Penaeus setiferus, were trawled in small quantities (42) between July and September. They were found more often in the eastern parts of the lake (Sta. 5-7) but were too rare to predict this as a normal pattern. One exception to this pattern was collection of 13 juvenile and adult white shrimp trawled from the St. Charles marsh (Sta. 14) in September.

The small numbers of penaeid shrimp taken in the present survey contrast sharply with previous surveys in Lake Pontchartrain (Suttkus et al. 1953a-c, 1954 a-f, 1955 a-b; Tarver and Savoie 1976). Catch effort values for 1978 were so small as to be meaningless, because the total for both species together was 98 adults for 34 hours (C/E = 2.9) of trawling in the lake and marsh between May and September. Suttkus et al. (1954b) showed annual figures of 6458 for Penaeus aztecus and 5527 for P. setiferus. Tarver and Savoie (1976) collected 683 P. aztecus but only 23 P. setiferus. For comparison, Suttkus et al. (1954d) had catch/effort figures averaging 166 brown shrimp/hour from May to August and 182 white shrimp/hour from July to September. Their catches of both species of shrimp extended for longer periods of time in the lake with

small numbers being caught into November. Realistic figures on the penaeid shrimp population in Lake Pontchartrain would require additional study in cooperation with both commercial and private sportsman to evaluate more accurate distributions and population densities. Furthermore, detailed studies would provide data on whether the populations of shrimp in Lake Pontchartrain are deteriorating and should give insight on halting any decline.

Our findings on blue crabs in Lake Pontchartrain are better than the data on shrimp but still might greatly underestimate the population because trawling is an inefficient gear for crabs. The blue crab population in Lake Pontchartrain is made up of a single species, Callinectes sapidus. There was no evidence of the presence of the lesser blue crab Callinectes similis in the lake although this species is present in Breton Sound (Williams 1974).

Blue crabs occurred in the lake year-round but were most abundant during the warmer months of summer and early fall. Adults and larger juveniles were more common in the open water collections (primarily trawls); smaller individuals were found inshore, particularly in the grassbeds. Similar to our findings on the penaeid shrimp, the few night seining collections showed the grassbeds to be potentially important nursery areas in the lake for the blue crab.

Darnell (1959) discussed the life history pattern of the blue crab in Lake Pontchartrain, and our data essentially agree with his findings. He postulated that mating takes place in the lake and is followed by migration of the mated females into higher saline waters. Paired crabs were occasionally taken in gill nets at Stations 4, 6, and 8 during

August and September. Observations made in the IHNC showed that blue crabs moving on an ebbing tide during August, September, and October were virtually all females.

Movement of the megalops larvae and the young transformed crabs into the lake is discussed in Chapter 15.

DISCUSSION

The present species total (85) compares well with those listed earlier for previous studies on the fishes of the lake. The differences between the present study and those of Tarver and Savoie (1976) and Suttkus et al. (1954d) seem, for the most part, to be attributable to the randomness of collecting certain relatively rare species. Our knowledge of the total membership of the Lake Pontchartrain fish community is probably incomplete, and there are most likely several additional freshwater and marine species that could be random visitors to the lake.

The order of abundance (Table 11) for the present study also agrees with these previous studies. The most abundant fish in Lake Pontchartrain during the survey by Tarver and Savoie (1976) and the second most abundant species taken by Suttkus et al. (1954d) was *Anchoa mitchilli*. Suttkus et al. (1954d) found *Micropogonias undulatus* and *Brevoortia patronus* to be the first and third most abundant species, respectively. *Menidia beryllina* was not as abundant as found in other surveys. Tarver and Savoie (1976) found the same four species as the present study to be the dominant lake members. Thus, there seems to be excellent agreement as to the most abundant fish species in Lake Pontchartrain. The abundance rank (relative to other members of the community) for the top 10 or 20 species probably changes somewhat (possibly due to successful

spawning classes), but overall there seems to be moderate agreement on the dominant community members between 1953 and 1978 in Lake Pontchartrain. Roughly 10 species (or fewer) make up over 90% of the fish population in the lake. This seems to be a general pattern found for most estuaries studied on the Atlantic and Gulf Coasts of the United States.

In comparison, however, with the Atlantic and Gulf of Mexico, Lake Pontchartrain has a somewhat anomalous fish community. This may be caused by interplay among the lake's following physical and chemical characteristics:

1) large size (1632 sq km)
2) shallow depth (5 m or less)
3) uniform bottom topography
4) lack of deep channels
5) relatively low salinity
6) low tidal ranges
7) restricted access to Gulf of Mexico

The fish community of Lake Pontchartrain is a transient one. Tyler (1971) found four groups of species in a study of a New Brunswick bay. He divided these into periodic and resident components of the community with an additional group he termed "occasional". He postulated that with increased annual temperature fluctuations, an estuary would have proportionately more periodic species and fewer resident members. The Lake Pontchartrain fish community is dominated by temporary species that move into the lake for periods of one to several months and then emigrate from the lake. This produces a multitude of different periodic groups

of species. There are periodic species that live in the lake for the entire year but have certain proportions of their members entering and/or leaving the lake. They are probably best thought of as "long-term periodic" species or "semiresident." Anchoa mitchilli, Micropogonias undulatus, and Brevoortia patronus all are examples of "long-term periodic" species that dominate the lake fish fauna (Suttkus 1954, 1956).

Sykes and Finucane (1965) found that Tampa Bay (like Lake Pontchartrain) played an important role as nursery grounds for many Gulf of Mexico fishes. They found 20 commercially important species of fishes that utilized the bay in some portion of their life cycle. During 1978, 47 species of fishes (many of them also of commercial significance) were taken in Lake Pontchartrain as young or immature. In addition, 36 species of young or immature fishes were taken in the surrounding marsh area. In Lake Pontchartrain many of these nursery species are found in the submerged grassbeds (Sta. 4, 5, and 17 - Fig. 1; Montz 1978). The concept of the estuary as an important nursery area has been noted in many studies (Haedrich and Hall 1976). Gunter (1938) showed that for many of the marine fishes along the Louisiana coast, the early part of their life cycle was estuary dependent. He noted "It is quite evident that the bay waters act as nursery grounds for many species studied here. The smaller fishes were practically always found inside while larger individuals were taken in the gulf." During 1978, nine species of marine fish (Table 21, group D) were present in the lake only as young or small juveniles on a transient basis.

The freshwater component of Lake Pontchartrain is also largely seasonal. Ictalurus furcatus is more abundant during colder, less

saline periods and moves into Lake Maurepas and the tributary rivers with the higher salinity and increasing temperatures of late spring and summer.

Haedrich (1975) and Haedrich and Hall (1976) argued that seasonal change in local fish communities is greatest in the healthiest temperate estuaries. This presumably allows the maximum possible number of fish species to utilize the resources of the estuary. Haedrich and Hall (1976) presented comparative data that illustrated seasonal percentage similarity being lowest (marked seasonal change) in an unpolluted community and highest (little seasonal change) in polluted areas. Polluted estuaries seem to have very static fish communities.

The Lake Pontchartrain fish community is marked by strong seasonal change. Seasonal similarity patterns (both number of species [S] and percent, based only on a "presence-absence" comparison) are given in Table 12. For contiguous seasons, the lake proper has values of 44% (winter-spring), 53% (spring-summer), and 63% (summer-fall); the respective marsh values are 48%, 52%, and 60%. These are lower than the "polluted area" figures and in the same range as "healthy areas" given in Haedrich (1975) and Haedrich and Hall (1976) although the overlap measurements are slightly different. Relative seasonal abundance presented in Tables 24 (lake) and 25 (marsh) also support the relatively low overall seasonal overlap. Very few species have three or four dominant seasons. Comparing diversity parameters on a seasonal basis (Table 28), there is significant (.05% level) difference between winter-spring, winter-summer, and winter-fall in the lake and between winter-summer and spring-summer in the marsh that also supports the contention of marked seasonal differences. The

temporary nature of the fish fauna of Lake Pontchartrain shows that there is dependence on Lake Maurepas, Lake Borgne, and other surrounding bodies of water for the completion of many life cycles.

The community structure of Lake Pontchartrain is probably kept stable by balanced interactions between the environment and the biota. This is a well-known principle in basic ecology. If stress is introduced by climatic flunctuations, external conditions, or influences by man, the organization and diversification processes will be altered. Competition probably increases, and species diversity may decline. Copeland (1970) noted that "diversity is therefore useful as an index of the amount of stress, whether natural, induced by pollution, or from other influences". Odum (1970) stressed that many estuarine residents are "living near the limit of their tolerance range" and thus are easy victims of environmental alteration. He listed five reasons why estuarine communities are particularly susceptible to deterioration from man's activities. These were:

1) nutrient trap effect
2) unique structure of estuarine food webs
3) harsh nature of physical conditions
4) sedimentary control of estuarine waters
5) key role of freshwater inflow

Copeland and Bechtel (1971), Bechtel and Copeland (1970), and Haedrich (1975) found a close correlation between species diversity and pollution levels in their long-term studies of Galveston Bay and Massachusetts estuaries. Haedrich (1975) presented annual diversity (H) values for nine estuaries in Massachusetts and ranked values according

to pollution levels. Annual diversity ($\log_e$) ranged from 0.40 to 2.40. The lowest figures generally were found in those estuaries where pollution levels were highest.

Table 29 presents comparative diversity (H) values (corrected to $\log_e$ where necessary) for selected estuarine areas on the Atlantic and Gulf Coast of the United States. Although the total range is 0 (Subrahmanyam and Drake 1975) to 3.58 (Moore 1978) most of the values range between 1 and 3. Most mean annual values presented seem to fall between 1 and 2.5. It should be cautioned that for comparison, all values should be corrected to a uniform log base (see Table 27 for comparative base values for Lake Pontchartrain). Studies of fishes from other areas of the world seem to be in the same range; for example, for Spanish Mediterranean coast: 1.0-2.4 (Margalef 1968), for Los Angeles Harbor: .65-2.08 (Stephens et al. 1974), for Colorado Lagoon, CA: .03-1.11 (Allen and Horn 1975), for Lower Medway Estuary, England: .25-1.89 (van den Broek 1979), and for Terminos Lagoon, Mexico: .53-2.5 (Yáñez-Arancibia et al. unpubl. M.S.). Haedrich and Haedrich (1974) noted low diversity values for the fish community in the Mystic River, which is heavily polluted in downtown Boston. McErlean et al. (1973) noticed a disturbing downward trend in the components of diversity studied in the Patuxent estuary in Maryland. They noted that "should these trends continue, structural complexity of an already simple system will be reduced . . . and may become subject to crashes and booms." Diversity (H) decreased during their five year study and, as they pointed out, "may be a harbinger" of the loss of an important function of the river, that of "nursery area" for juvenile fishes. For Lake Pontchartrain, at the present time, there are no data on the trends in community structure.

Should the lake no longer act as a nursery, there could be great repercussions throughout the entire southeast Louisiana estuarine system if these species do depend on Lake Pontchartrain as their primary nursery because as Haedrich and Hall (1976) noted, most fish that spend their juvenile periods in estuaries do not stay there as adults.

SUMMARY

The nekton of Lake Pontchartrain was studied for 12 months in 1978, and basic information was obtained on the fish fauna. Eighty-five species and over 80,000 specimens were collected from 17 stations in the lake and surrounding marsh. The fauna is dominated by four species, *Anchoa mitchilli*, *Micropogonias undulatus*, *Brevoortia patronus*, and *Menidia beryllina*, that make up roughly 80% of fish population. Fifty-five species were classified as lake species; 22, as marsh species; and 8 had affinities in both areas. The fish fauna of Lake Pontchartrain was considered very transient; 27 species were found in the lake and 26 species were found in the marsh during all four seasons.

Four components of community diversity were studied monthly and seasonally using information theory indices. These components provide numerical evaluation of the fish populations and a basis for comparison for detection of potential future alterations in the lake. We strongly recommend that future comparisons of the lake fish fauna take into account the strong seasonal nature of the fish fauna because this may provide a means of monitoring environmental stress on the estuary. At the present time, the overall fish community seems to be moderately healthy.

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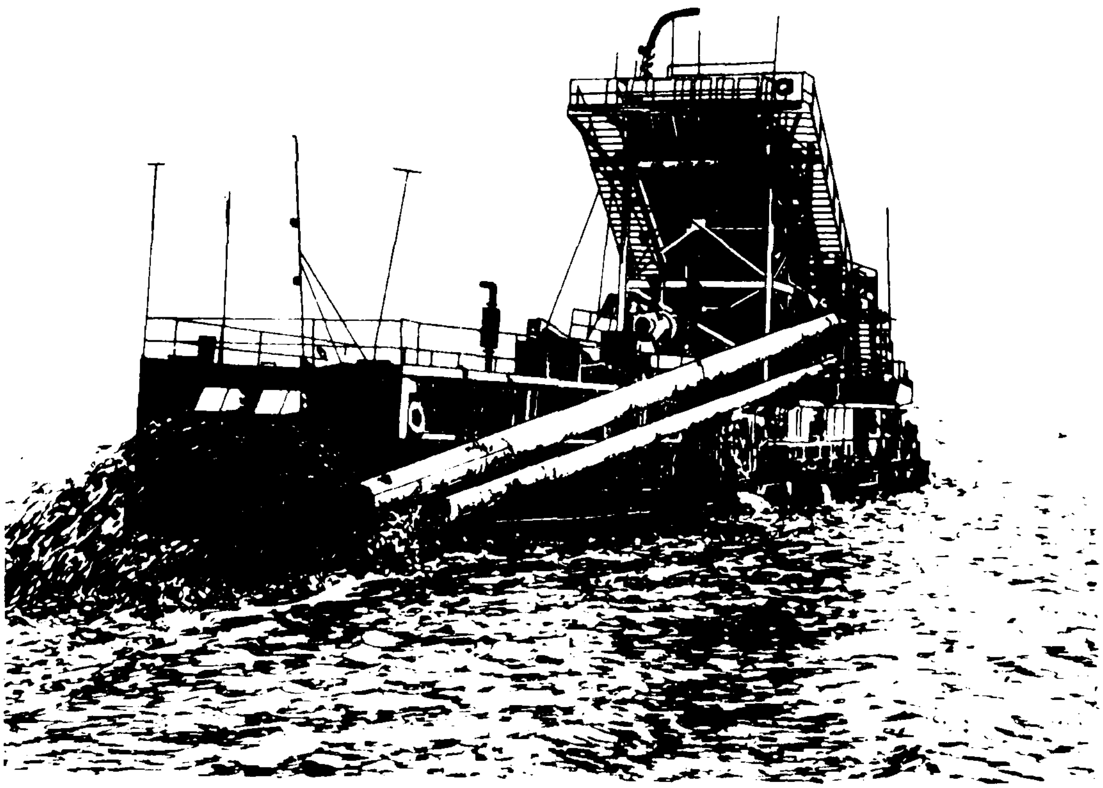

Stern view of shell dredge

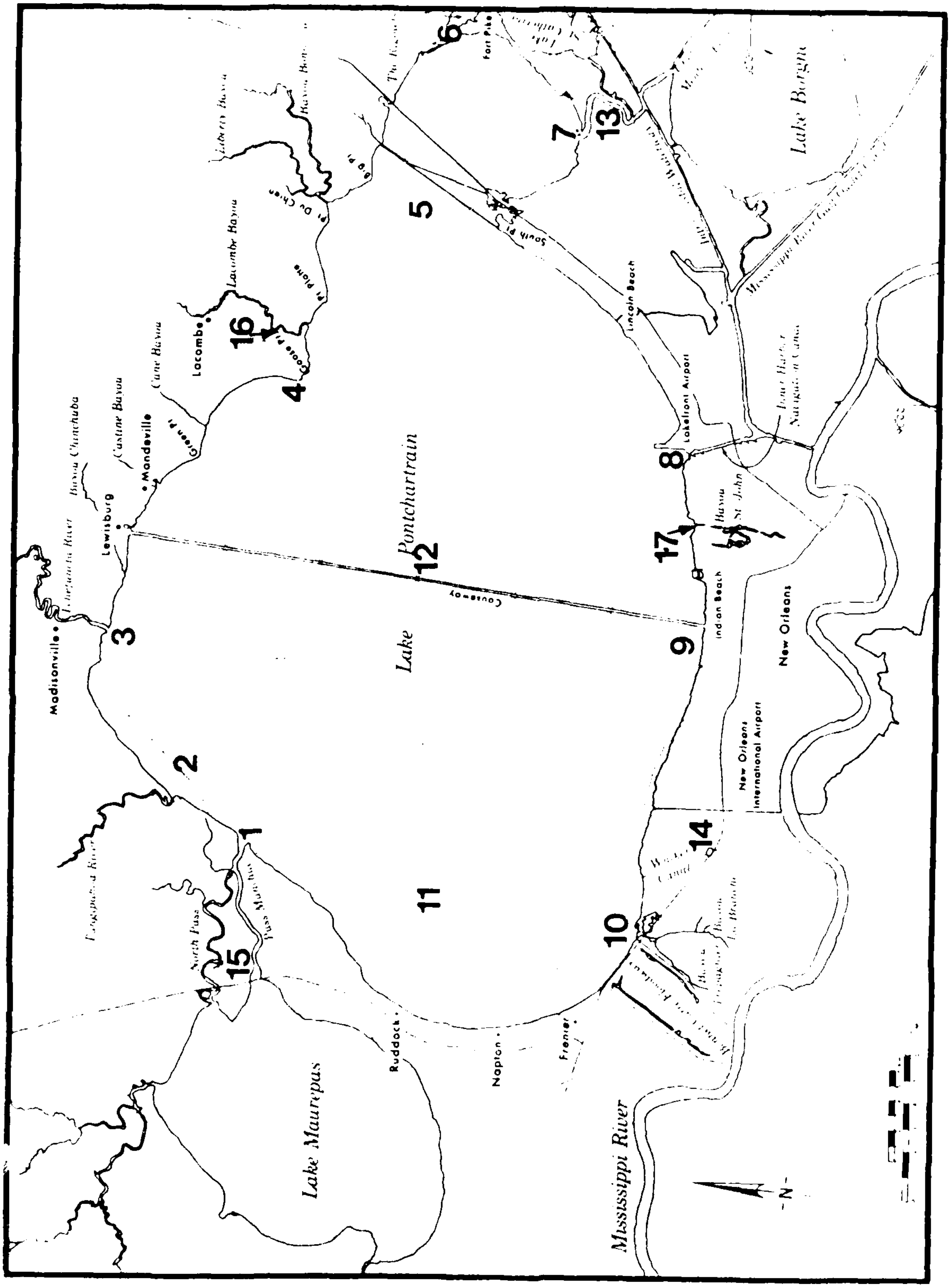

Figure 1. Lake Pontchartrain, LA,nekton stations 1-17, 1978.

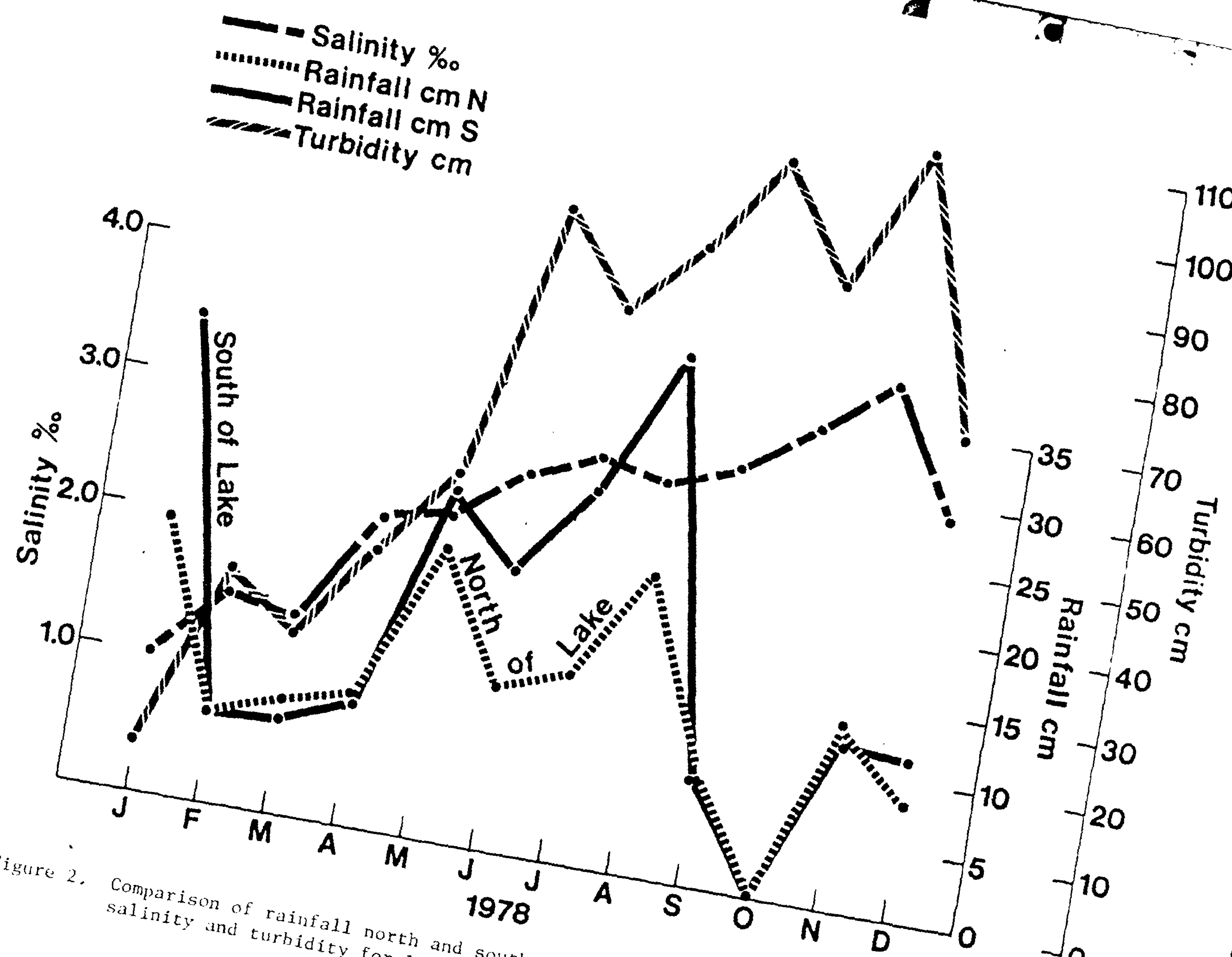

Figure 2. Comparison of rainfall north and south of Lake Pontchartrain, LA, and Lake Pontchartrain salinity and turbidity for 1978.

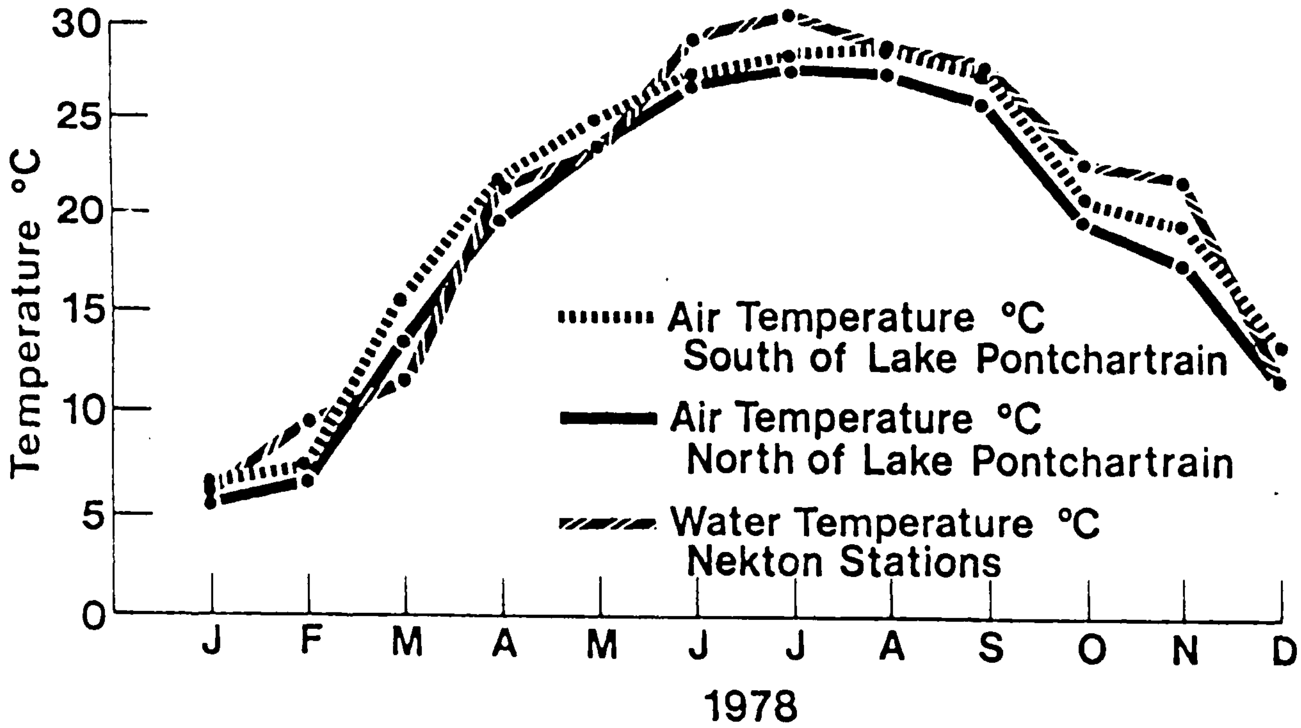

Figure 3. Comparison of monthly air temperatures north and south of Lake Pontchartrain, LA, and water temperatures for 1978.

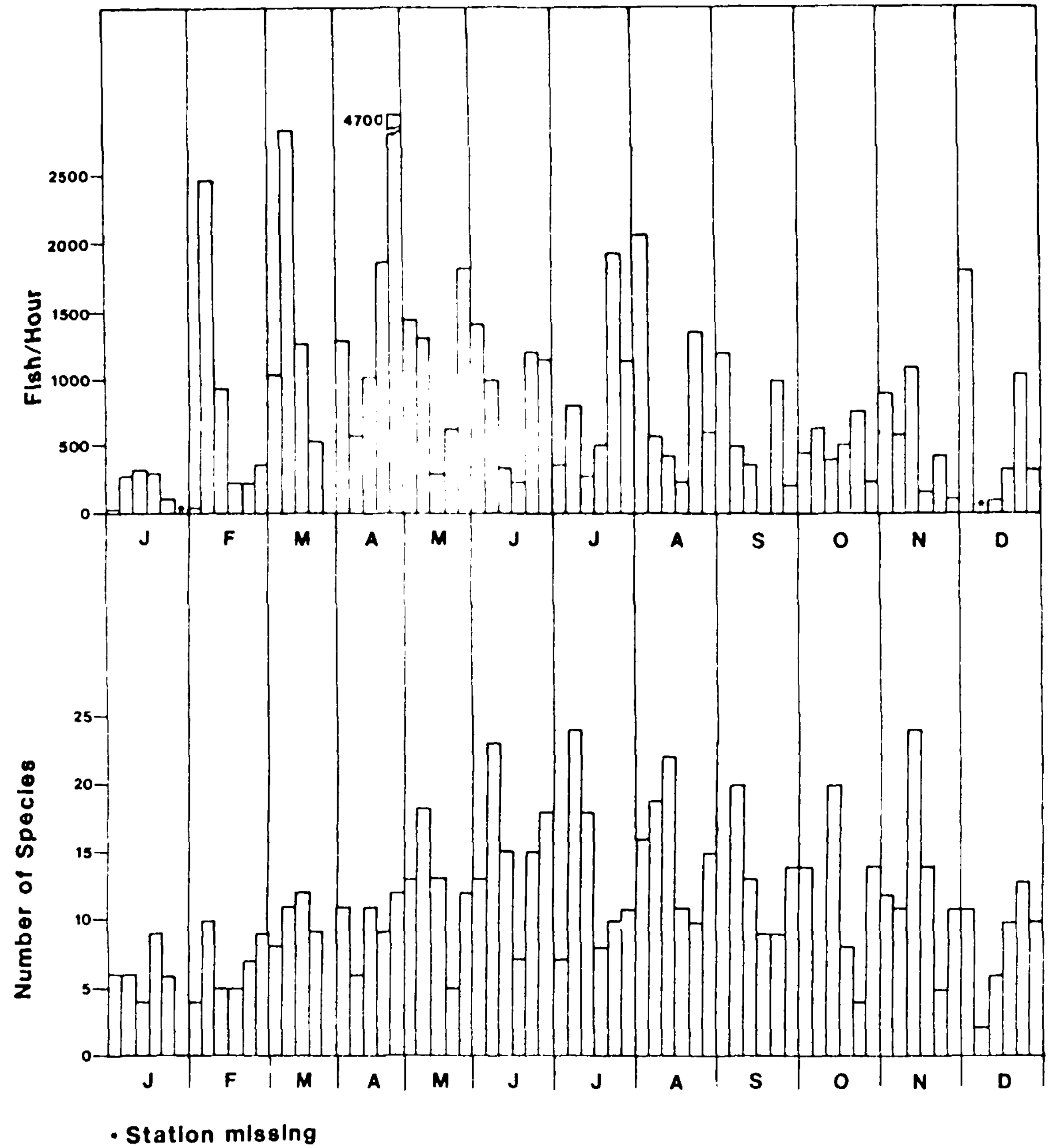

Figure 4. Catch effort (top) and number of species (S) (bottom) in Lake Pontchartrain, LA. for seine collections, by station (2, 3, 4, 6, 8, 10, 17), 1978.

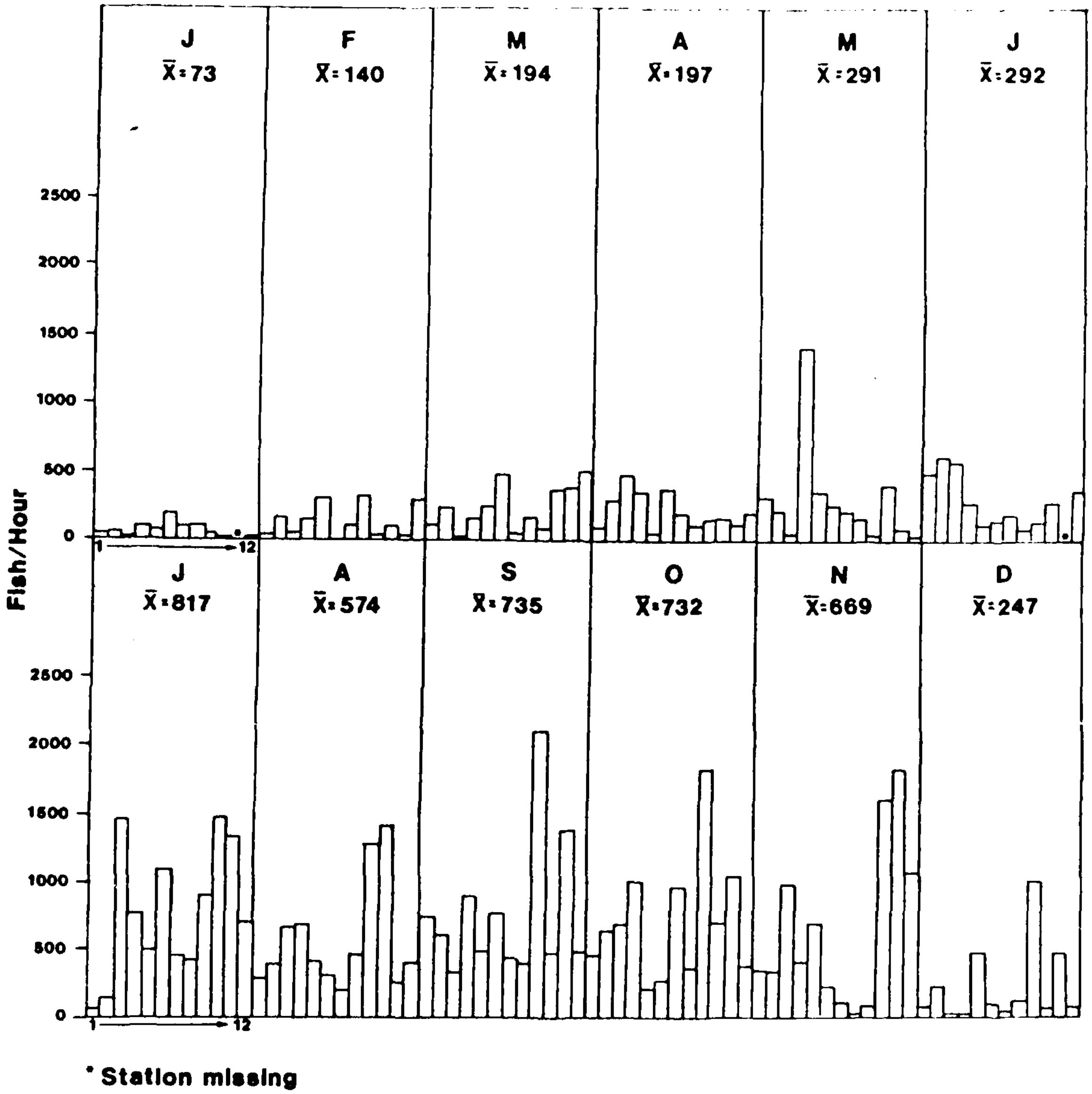

Figure 5. Catch effort in Lake Pontchartrain, LA, for trawl collections, by Station (1-12), 1978.

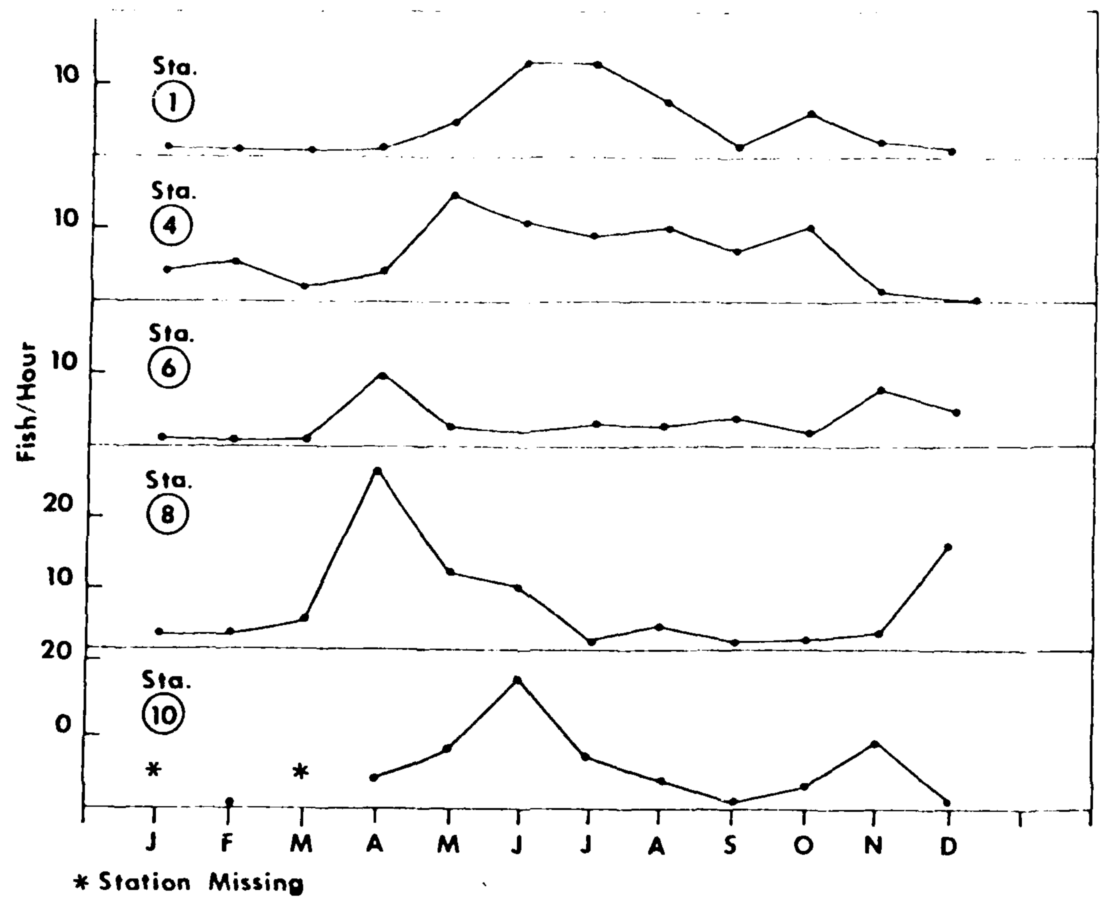

Figure 6. Catch effort for stationary nets in Lake Pontchartrain, LA, during 1978.

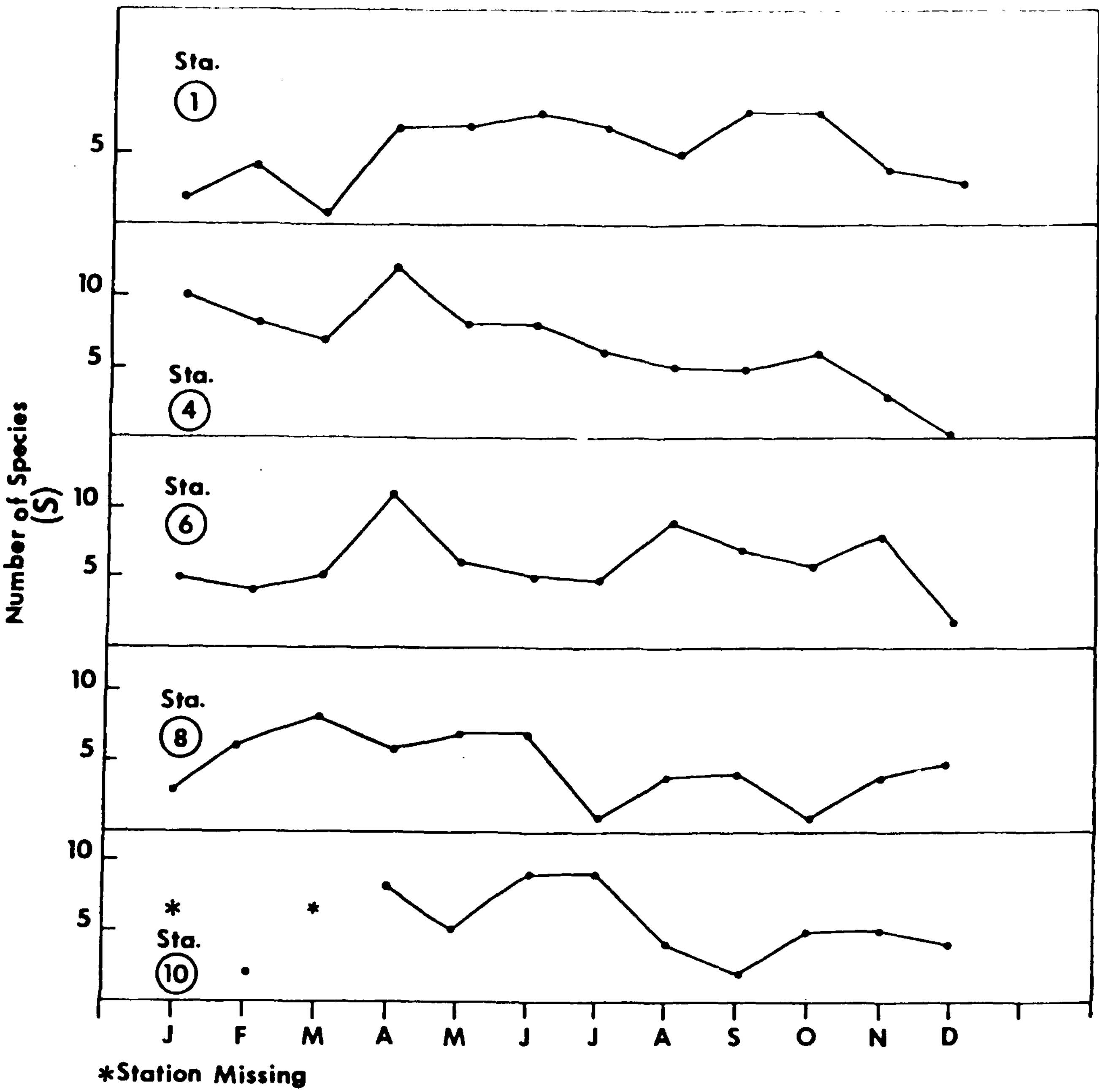

Figure 7. Number of species collected by stationary nets in Lake Pontchartrain, LA, during 1978.

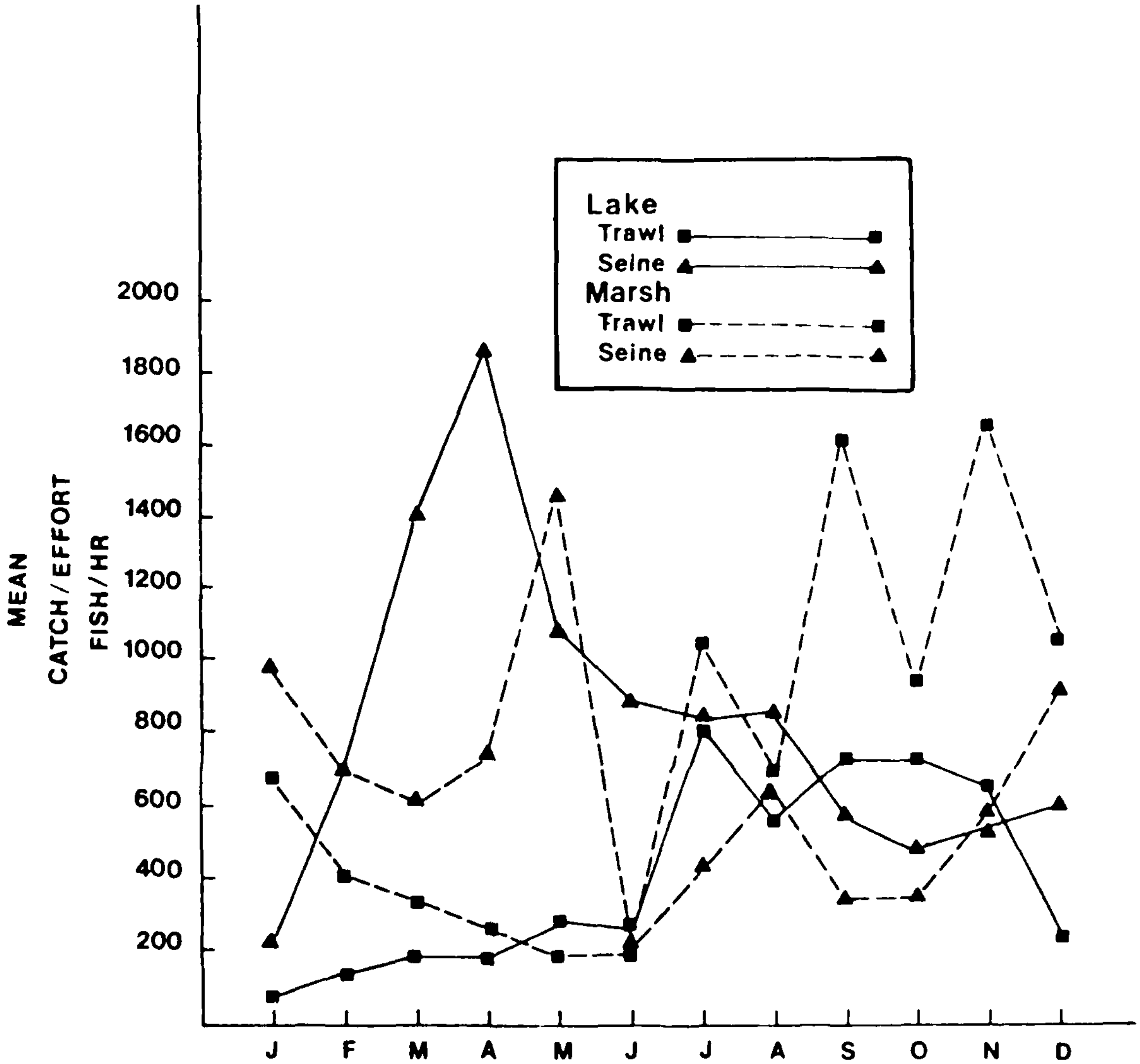

Figure 8. Comparison of mean monthly catch effort (trawls and seines) for Lake Pontchartrain, LA, and surrounding marsh area, 1978.

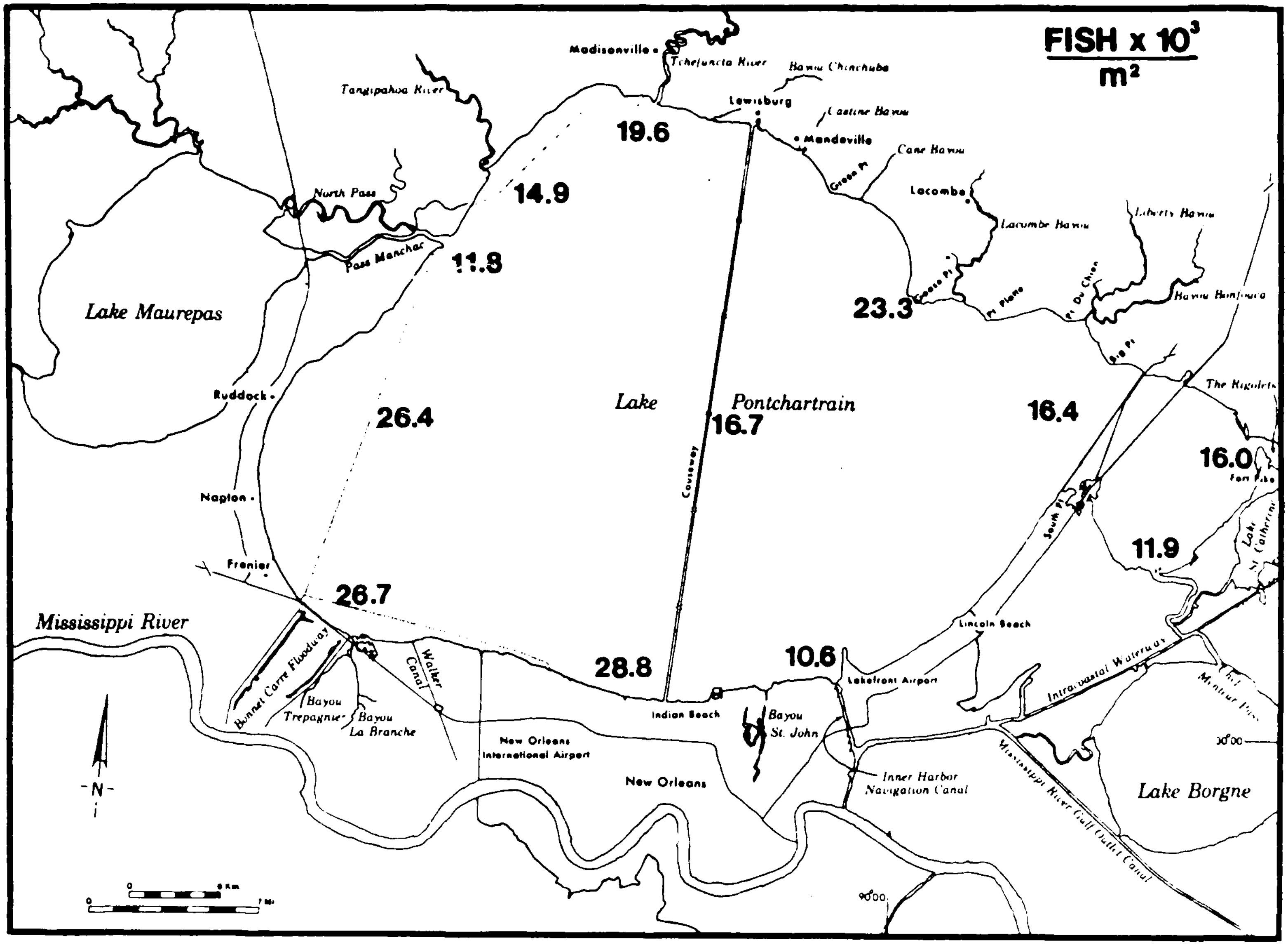

Figure 9. Yearly station population density estimates (fish x $10^3/m^2$) for demersal fish trawled in Lake Pontchartrain, LA, 1978 (cf. Figure 1 for identification of stations).

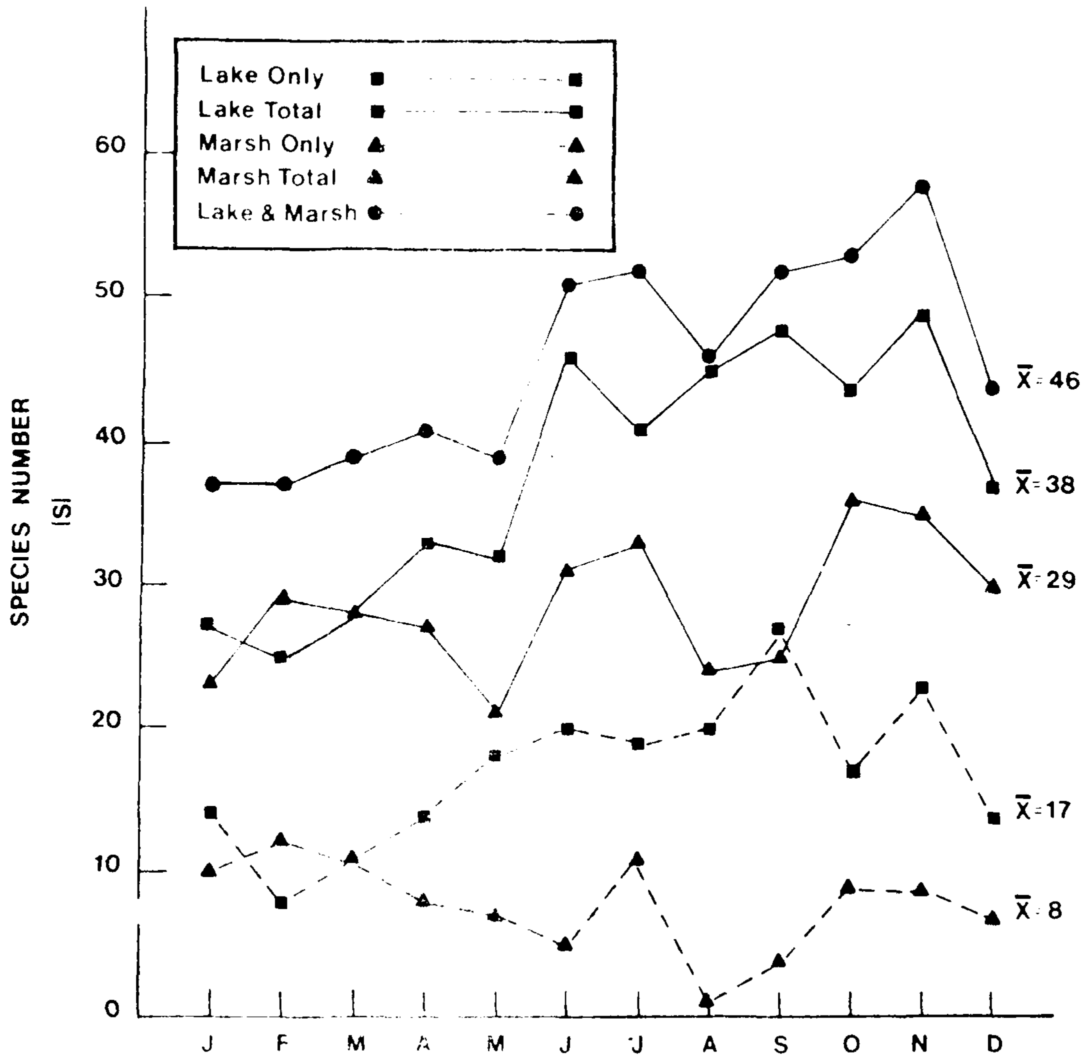

Figure 10. Comparison of number of species (S) of fishes collected in Lake Pontchartrain, LA, and surrounding marsh areas, 1978.

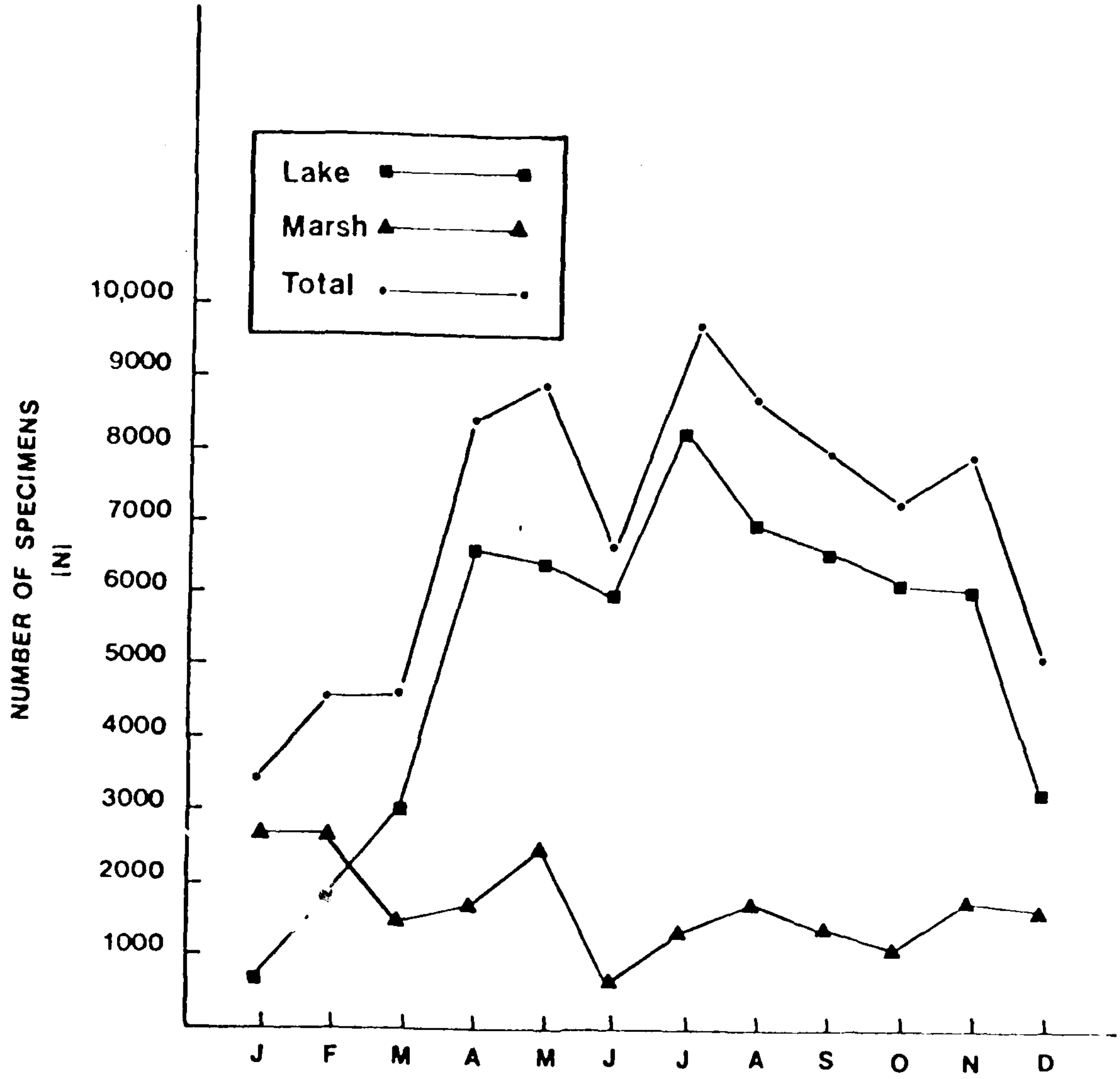

Figure 11. Comparison of number of specimens (N) of fishes collected in Lake Pontchartrain, LA, and surrounding marsh area, 1978.

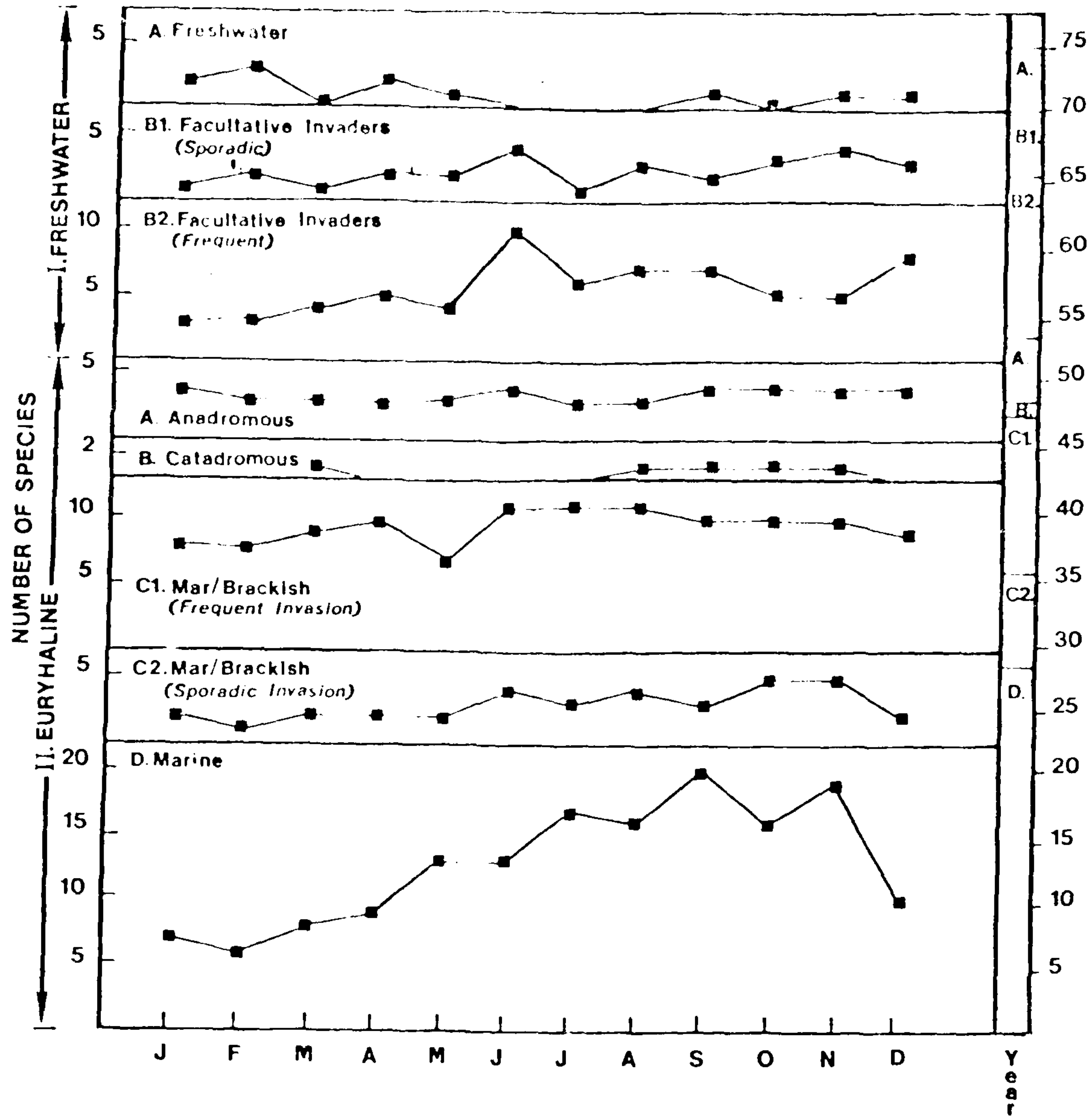

Figure 12. Monthly total of the number of fish species in Lake Pontchartrain, LA, in the eight salinity tolerance groups, 1978.

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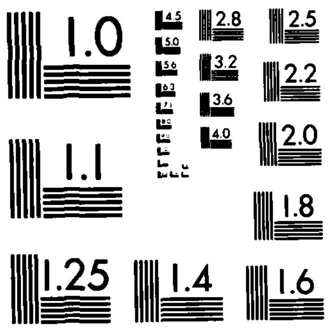

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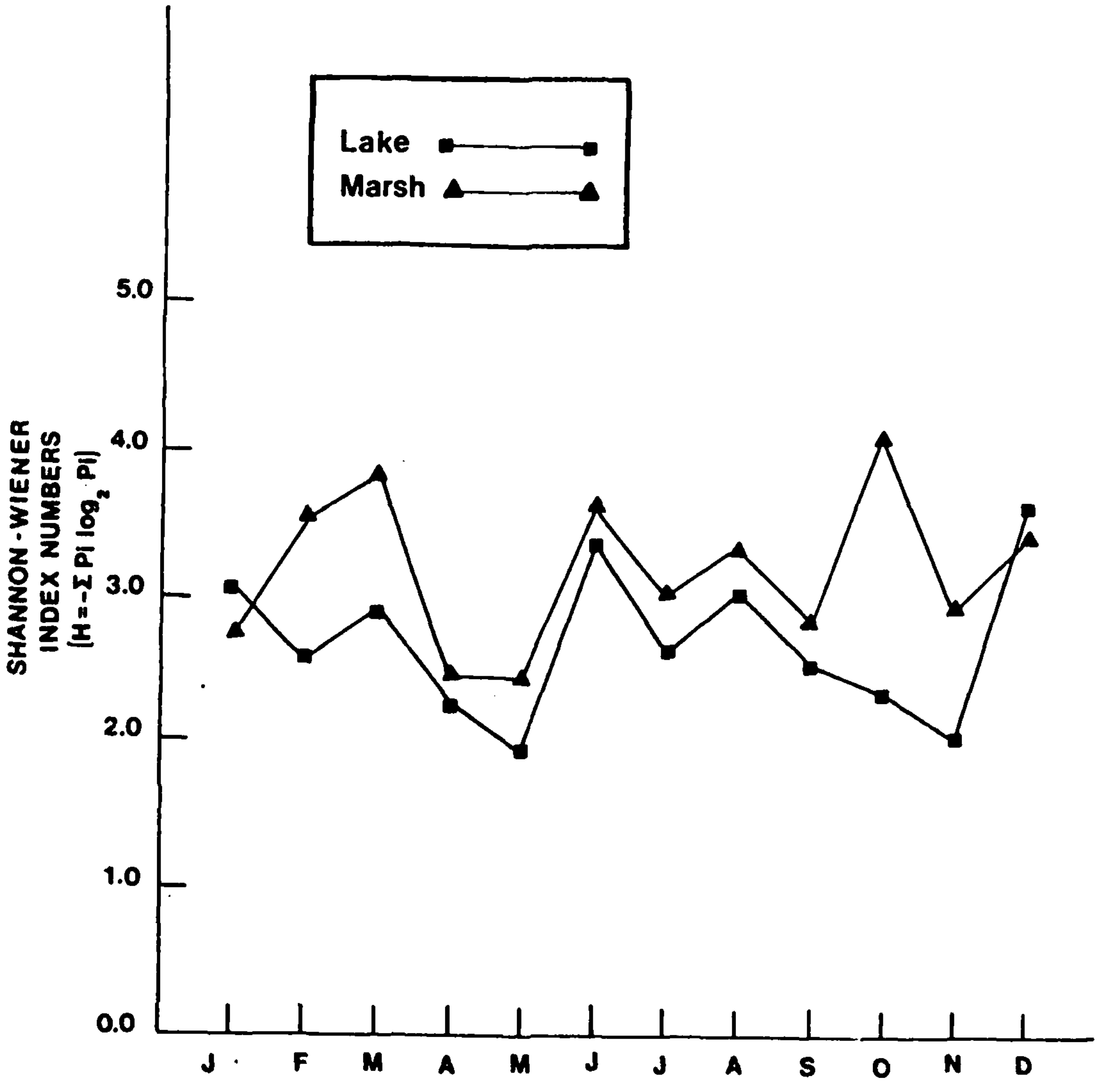

Figure 13. Comparison of lake and marsh diversity index (H), in Lake Pontchartrain, LA,1978.

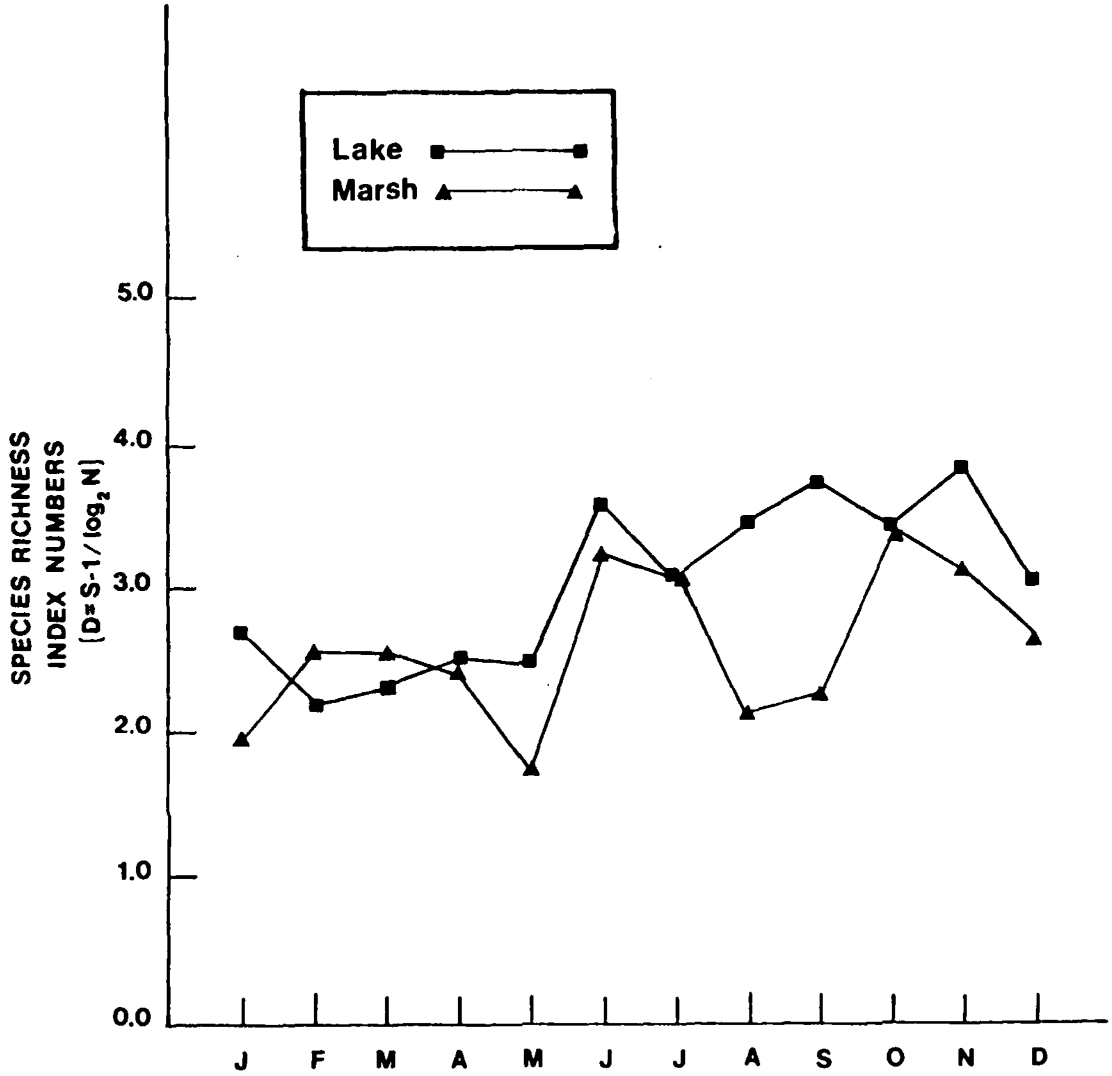

Figure 14. Comparison of species richness index (D) for Lake Pontchartrain, LA, and surrounding marsh area, 1978.

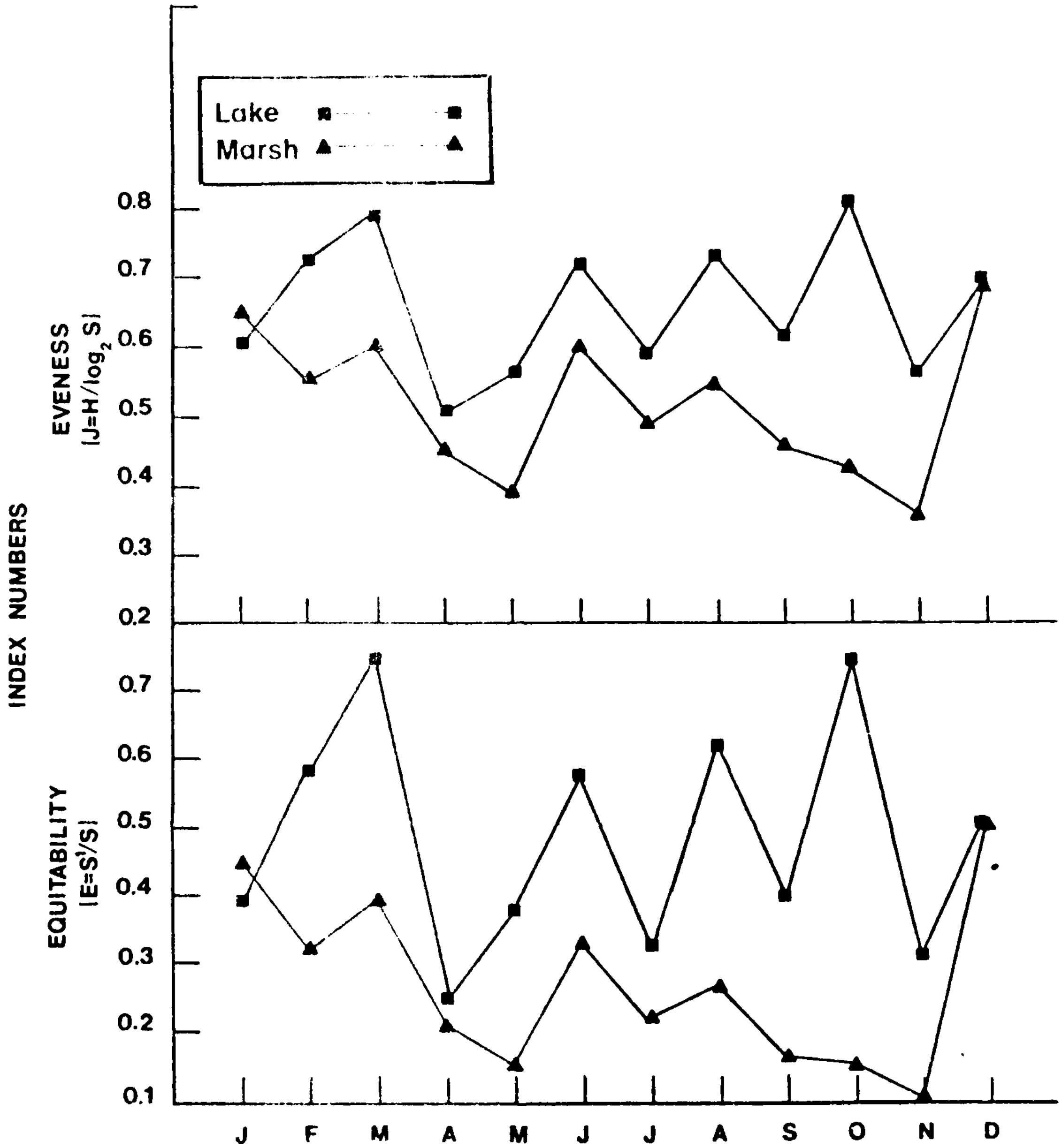

Figure 15. Comparison of two components of species evenness, Equitability (E), and evenness (J), for Lake Pontchartrain, LA, and surrounding marsh area, 1978.

Table 1. Measured Salinities (‰) for Lake Pontchartrain and Surrounding Marsh Area for 1978

STA #*	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	MIN	MONTH	$\bar{X}$	MAX	MONTH
1	0	.8	.9	2	.9	1.2	1.3	1.3	1.1	2.4	1.8	1	0	1	1.2	2	4
2	0	.3	.1	.4	1	.8	.7	.7	.6	1.4	.5	.5	0	1	.6	1.4	10
3	0	1	1.5	2	1.2	1	1.5	1.8	1	1.2	1.8	1.1	0	1	1.3	2	4
4	0	2.3	1.9	2.1	3	2.2	1.9	1.3	1.9	2.5	3	3.8	0	1	2.2	3.8	12
5	2.5	3.1	1.8	2.4	4.6	3.1	3.5	2.8	4	3.9	5.1	3.7	1.8	3	3.4	5.1	11
6	2	1.9	2.7	2.1	3.2	2.7	4.2	3.9	4.5	5.5	8.5	3.6	1.9	2	3.7	8.5	11
7	3	3.1	1.8	4	3.7	5.2	5	4.2	5	5.5	6.8	4	1.8	3	4.3	6.8	11
8	.5	1.8	.6	3	2.4	4.3	3.2	4	5.2	5	4	5.5	.5	1	3.3	5.5	12
9	.5	.9	1.2	2.4	2.1	2.9	3.5	3.9	3.8	3.8	3.5	2.9	.5	1	2.6	3.9	8
10	0	.6	1.0	1.8	2	2.1	3	3	2.8	2.5	2	2.2	0	1	1.9	3	7,8
11	---	.5	.9	2	1.3	2.5	2.8	---	2.3	2.0	2.5	2.8	.5	2	2.0	2.8	7,12
12	3	2	1.8	2.3	2.2	3.5	2.7	2.8	3.2	3.4	4.5	3.6	1.8	3	2.9	4.5	11
17	---	---	---	---	---	3.2	4.2	4	4	4.5	4.8	3.1	3.1	12	4.0	4.8	11
Lake $\bar{X}$	1.0	1.5	1.4	2.2	2.3	2.7	2.9	2.8	3.0	3.4	3.8	2.9	.9		2.6	4.2	
13	1	3.2	1.8	4.2	3.8	5	5	4.4	6.7	5.3	5.6	4	1	1	4.2	6.7	9
14	0	.7	.9	0	1	2	2.8	2.2	2	3	3	2	0	1	1.7	3	10,11
15	0	1.6	.5	.3	1	1.5	1.5	.8	.3	.8	.4	.8	0	1	.8	1.6	2
16	0	.3	.3	.2	0	0	.8	.3	---	2.3	2.8	1	0	1	.8	2.8	11
Marsh $\bar{X}$	0.3	1.5	0.9	1.2	1.5	2.1	2.5	1.9	3.0	2.9	3.0	2.0					

*For station locations, see Figure 1.

Table 2. Classification of Lake Pontchartrain Nekton Stations by Salinity*

STATION	SALINITY RANGE (°/₀₀)	SALINITY ZONE
LAKE		
1	0 - 2.0	limnetic, beta-oligohaline
2	0 - 1.4	limnetic, beta-oligohaline
3	0 - 2.0	limnetic, beta-oligohaline
4	0 - 3.8	limnetic, alpha & beta-oligohaline
5	1.8 - 5.1	alpha & beta-oligohaline, beta-mesohaline
6	1.9 - 8.5	alpha & beta-oligohaline, beta-mesohaline
7	1.8 - 6.8	alpha & beta-oligohaline, beta-mesohaline
8	0.5 - 5.5	alpha & beta-oligohaline, beta-mesohaline
9	0.5 - 3.9	alpha & beta-oligohaline
10	0 - 3.0	limnetic, beta-oligohaline
11	0.5 - 2.8	beta-oligohaline
12	1.8 - 4.5	alpha & beta-oligohaline
17	3.1 - 4.8	alpha-oligohaline
MARSH		
13	1.0 - 6.7	alpha & beta-oligohaline, beta-mesohaline
14	0 - 3.0	limnetic, beta-oligohaline
15	0 - 1.6	limnetic, beta-oligohaline
16	0 - 2.8	limnetic, beta-oligohaline

Yearly averages

<u>Lake</u>
limnetic (0-0.5): none
beta-oligohaline (0.5-3.0): Sta. 1-4, 9-12 (8 stations)
alpha-oligohaline (3.0-5.0): Sta. 5-8, 17 (5 stations)

<u>Marsh</u>
limnetic: none
beta-oligohaline: 14-16 (3 stations)
alpha-oligohaline: 13 (1 station)

*Classification based on 1958 "Symposium on the Classification of Brackish Waters-Venice System" (Remane and Schlieper 1971).

Table 3. Salinity Data Recorded from Previous Studies of Lake Pontchartrain

Date	Salinity	Area	Reference
1953/54	1.2-12.2°/₀₀	Entire lake	Suttkus _et_ _al_. (1954d)
1967/69	1 - 10 °/₀₀	Entire lake	Davis _et_ _al_. (1970)
1968	0.0-7.4°/₀₀	Entire lake	Stern _et_ _al_. (1968)
1968/69	0.2-5.9°/₀₀	New Orleans shore	Stern and Stern (1969)
1970/72	0.6-8.6°/₀₀	Entire lake	Tarver and Dugas (1973)
1973	0.2-2.4°/₀₀ (a)	New Orleans shore	Poirrier and Mulino (1975) and Poirrier _et_ _al_. (1975)
1972/74	0.0-18.9°/₀₀	Entire lake	Tarver and Savoie (1976)
1975	0.3-2.8°/₀₀ (a)	New Orleans shore	Poirrier and Mulino (1977)
1978	0.0-8.5°/₀₀	Entire lake	Present study

(a) Bonnet Carre Floodway opened.

Table [illegible]. Water Temperature ([illegible]) for Lake Pontchartrain and Surrounding Marsh Area for 1978

STA*	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	MIN	MONTH	$\bar{X}$	MAX	MONTH
1	7	8.3	11.5	23	23	29	30	27.3	28	20	21	10.9	7	1	19.9	30	7
2	7	9.7	10.5	23	23	31	32	26	28	24	21	11.8	7	1	20.6	32	7
3	6	11.1	10.5	24	23	29	32	27	29	22	21	10.9	6	1	20.3	32	7
4	6	9.9	12	21.5	22.5	30	31.5	29.5	27	20	21	10	6	1	20.0	31.5	7
5	5	9.4	11	20	21.5	28	29.5	28.5	27.5	20.5	21	11.6	5	1	19.5	29.5	7
6	5	7.8	11.5	20	22	28	29	30	28	23	21	11.5	5	1	19.7	30	8
7	5	7.8	11.5	20	23	28	29	30	28.5	24	21.8	11.8	5	1	20.0	30	8
8	8	10	12	19.5	25	28	30.5	29	28	25.5	22	13	8	1	20.9	30.5	7
9	7	10	10	20	24	30	30	29.5	28	23	22	10.9	7	1	20.4	30	6,7
10	7	10	13	21.5	25	28	29	29.5	27	24	24	10.5	7	1	20.7	29.5	7
11	---	11	11	22	23	29	32	---	27.5	23.5	23	11	11	2	21.3	32	7
12	5	10	12	19.5	22.5	30	30	27.2	27.5	21.5	23	12	5	1	20.0	30	6,7
17	---	---	---	---	---	30	30	30.2	28	24.5	22	12	12	12	25.2	30.2	8
Lake $\bar{X}$	6.2	9.5	11.4	21.2	23.1	29.1	30.3	28.6	27.8	22.7	21.8	11.4	7		20.7	30.6	
13	10.5	7.8	---	20	24	28	29	32	29	24	22.5	11.2	7.8	2	21.6	32	9
14	9	10	12	25	27.5	29	31	30	28.5	24	25	11	9	1	21.8	31	7
15	6	8.3	17.5	25	26	30	28	26.9	28.8	20.5	25	12	6	1	21.2	30	6
16	5	7.8	12	19	24	30	29	29.9	---	23	22	12	5	1	19.4	30	6
Marsh $\bar{X}$	7.6	8.5	13.8	22.3	25.4	29.3	29.3	29.7	28.8	22.9	23.6	11.6					

*For station locations, see Figure 1.

Table 5. Rainfall and Air Temperature for Area Surrounding Lake Pontchartrain, LA, for 1978

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	TOTAL
RAINFALL[1] Cm	34.4	6.4	6.8	8.8	24.7	19.9	26.3	37.3	7.6	0.0	11.9	11.2	195.1
DEP. from NORM	23.1	-5.8	-7.2	-1.8	14.0	7.8	9.2	23.9	-6.6	-5.7	2.0	-1.8	20.1
RAINFALL[2] Cm	19.3	6.4	8.1	9.4	20.2	11.9	13.3	21.0	8.7	.1	13.0	8.1	139.5
DEP. from NORM	7.1	-6.9	-6.9	-3.1	7.8	- .4	-3.0	7.7	-3.3	-7.1	2.5	-6.8	-12.4
AIR TEMP[1] °C	6.7	7.2	15.5	21.9	24.9	27.3	28.1	28.4	27.3	20.9	19.5	13.3	
DEP. from NORM	-4.9	-4.9	- .4	1.6	1.0	.4	.4	.7	1.7	- .1	3.9	.6	
AIR TEMP[2] °C	5.6	6.6	13.3	19.5	23.7	26.8	27.7	27.2	25.9	19.4	17.7	11.1	
DEP. from NORM	-5.0	-5.6	-1.9	- .3	.4	.3	.2	- .1	.9	.6	3.1	- .3	

[1]Data from NOAA station at New Orleans International Airport, Monthly Summary.

[2]Data for East Central Section of Louisiana from NOAA Climatological Data-Louisiana 83(1-12) 1978.

Table [illegible]. Secchi Disc (Turbidity) Reading (Cm) for Lake Pontchartrain and Surrounding Marsh Area for 1978

STA #*	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	MIN	MONTH	$\bar{X}$	MAX	MONTH
1	5	25	20	20	20	105	55	80	91	30	125	47.5	5	1	55	125	11
2	5	42.5	20	20	20	80	65	67.5	90	60	30	42.5	5	1	45	90	9
3	3	50	65	20	25	130	125	120	120	120	135	134	3	1	87	135	11
4	5	23	30	20	60	70	70	82.5	142.5	102.5	165	117.5	5	1	74	165	11
5	2	30	25	60	90	110	72	85	90	110	95	98	2	1	72	110	10
6	10	56.5	25	40	90	90	70	75	50	80	100	85	10	1	64	100	11
7	12	50	35	40	40	100	70	70	70	85	100	90	12	1	64	100	6,11
8	17	25	10	53	80	90	106	90	110	110	160	82	10	3	78	160	11
9	13	20	10	50	50	90	100	105	120	115	150	40	10	3	72	150	11
10	5	16	15	76	67	63	36	140	135	73	80	32.5	5	1	62	140	8
11	---	24	20	20	20	80	50	---	100	90	80	20	20	4,5,12	50	100	9
12	2	34	40	50	60	100	100	68	90	85	70	60	2	1	63	100	6,7
17	---	---	---	---	---	100	120	110	150	100	120	55	55	12	108	150	9
Lake $\bar{X}$	7	33	26	39	52	93	80	91	105	89	109	70	11		69	125	
13	2	23	15	40	35	42.5	60	45	50	95	100	45	2	1	46	100	11
14	12.5	17.5	20	22.5	25	40	42.5	40	22.5	40	30	27.5	12.5	1	28	42.5	7
15	14	10	20	30	22.5	80	40	40	50	47	50	65	10	2	39	80	6
16	---	41	15	40	50	50	50	65	---	100	85	60	15	3	56	100	10
Marsh $\bar{X}$	8	23	17	31	33	53	48	48	41	71	66	49					

*For station location, see Figure 1.

Table 7. Number of Species (S) and Specimens (N) Collected in Lake Pontchartrain, LA and Surrounding Marsh Area, 1978

	A Total monthly species (S) (Lake + marsh)	B Species taken only in Lake	C Total species taken in Lake	D Species taken only in marsh	D Total species taken in marsh	Total (N) specimens	Lake specimens	Marsh specimens
JAN	37	14	27	10	23	3441	793	2648
FEB	37	8	25	12	29	4575	1899	2676
MAR	39	11	28	11	28	4607	3076	1531
APR	41	14	33	8	27	8426	6642	1784
MAY	39	18	32	7	21	8967	6424	2543
JUN	51	20	46	5	31	6646	6002	644
JUL	52	19	41	11	33	9728	8366	1362
AUG	46	20	45	1	24	8790	7042	1748
SEP	52	27	48	4	25	8051	6641	1410
OCT	53	17	44	9	36	7388	6200	1188
NOV	58	23	49	9	35	7962	6152	1810
DEC	44	14	37	7	30	5128	3374	1754
$\bar{X}$	46	17	38	8	29	6976	5218	1758
Mdn	45	17.5	39	8.5	28.5	7675	6176	1751
S	7.25	5.25	8.69	3.24	4.76	2858.8	2331.2	614.2
CV	15.85	30.74	22.92	41.38	16.70	40.98	44.68	34.94
1978 total	85	27	75	10	58	83709	62611	21098

Table 5. Relative Abundance of Fish Species Collected in Lake Pontchartrain, LA 1978

		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total	Percent catch
1.	Anchoa mitchilli	125	125	684	1187	855	2019	2519	3155	2797	3757	3909	535	22067	35.2
2.	Micropogonias undulatus	79	251	716	757	831	814	3236	799	1821	543	793	727	11367	18.2
3.	Brevoortia patronus	18	127	685	3419	3950	404	173	26	24	52	43	155	9076	14.5
4.	Menidia beryllina	281	736	220	590	229	731	854	676	674	245	577	308	6121	9.8
5.	Syngnathus scovelli	1	1	5	7		172	246	416	413	534	350	74	2219	3.5
6.	Cyprinodon variegatus	7	37	284	71		356	2	514	1	3	19	350	1644	2.6
7.	Leiostomus xanthurus			161	260	189	158	296	80	104	41	48	42	1379	2.2
8.	Arius felis				18	65	55	165	156	215	428	7		1109	1.8
9.	Lucania parva	11	18	13	91	1	91	98	287	30	98	66	134	938	1.5
10.	Fundulus grandis	22	11	13	22	10	349	9	155	20	13	14	85	723	1.2
11.	Mugil cephalus	121	29	134	53	72	92	66	54	12	9	13	13	688	1.1
12.	Cynoscion arenarius	2	1			1	8	321	57	80	28	36	36	570	0.9
13.	Poecilia latipinna				9		104		113			8	297	531	0.8
14.	Gambusia affinis		3	2	15		251		23	1	1		224	520	0.8
15.	Gobiosoma bosci			12	4		51	4	179	81	57	76	6	470	0.8
16.	Trinectes maculatus	17	14	16	40	37	22	42	30	3	6	10	120	357	0.6
17.	Cynoscion nebulosus	12	14	12	5	5	14	33	59	52	53	21	28	308	0.5
18.	Ictalurus furcatus	15	47	30	19	31	1	2	15	2	18		90	270	0.4
19.	Alosa chrysochloris	8	3	5	15	32	64	11	7	1	12	9	46	213	0.3
20.	Membras martinica*						65	113	4		9	3	1	195	0.3
21.	Dorosoma petenense	4	26	10			1		11	104	18	1	13	188	0.3
22.	Gobiesox strumosus*					1	21	23	23	15	63	25		171	0.3
23.	Dorosoma cepedianum	27	23	35	19	5	5	1		3	5	20	14	157	0.3
24.	Lepomis microlophus	1					2	14	23	50	40	5	2	137	0.2
25.	Strongylura marina				1	11	36	21	13	13	28	4	1	128	0.2
26.	Pogonias cromis	3	1	1	1	51	2	2	13	3	18	1	14	110	0.2
27.	Archosargus probatocephalus	17	7	4	3	10	23	9	5	6	12	12	2	110	0.1
28.	Syngnathus louisianae*							26	39	8	12	3		88	0.1
29.	Micropterus salmoides					1	7	17	12	18	12	4	2	73	0.1
30.	Lepomis macrochirus						1	1	23	8	19	4	5	61	0.1
31.	Ictalurus punctatus	13	15	1	7	14	1		1	3	2	2	1	60	0.1
32.	Lepomis punctatus						3	1	11	14	8	1	6	44	T
33.	Lagodon rhomboides					3	8	2	23	5	3			44	T
34.	Bairdiella chrysura			1			13	10	2	14	2	1		43	T
35.	Bagre marinus*				1	2	1	14	2	14				34	T
36.	Heterandria formosa				6	1	1		1		8	2	15	34	T
37.	Fundulus pulvereus						13		4				12	29	T
38.	Sciaenops ocellata*	1		1	2	1	3			2		10	5	28	T
39.	Dormitator maculatus*						19	2	3				3	27	T
40.	Carcharhinus leucas*						7	16	3					26	T
41.	Oligoplites saurus*							1	3	3	16	1		24	T
42.	Elops saurus					1		6	10	4				21	T
43.	Microgobius gulosus				2	5	1	1	1	1	7	3		21	T
44.	Paralichthys lethostigma	1	2	5	2	1				2	2	4		19	T
45.	Anguilla rostrata			1					2	3	7	4		17	T
46.	Dasyatis sabina				3		3		1	4	2	3		16	T
47.	Aplodinotus grunniens	3	3		1	5				1			2	15	T
48.	Lepisosteus spatula	1			7	2	1	3						14	T
49.	Gymnothorax plagiusa*										3	10		13	T
50.	Citharichthys spilopterus*									3		1		12	T

* ...ted only in lake.

... = trace; less than ...

Table 8. (Continued)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total	Percent catch
51. Gobionellus boleosoma*										1	10		11	T
52. Lepisosteus osseus			1						2		4		7	T
53. Prionotus tribulus*											7		7	T
54. Lepisosteus oculatus			1		1	2	1		1				6	T
55. Anchoa hepsetus*						5	1						6	T
56. Polydactylus octonemus*								3	3				6	T
57. Pylodictis olivaris		1		4									5	T
58. Menticirrhus americanus*					1					3		1	5	T
59. Morone mississippiensis		3											3	T
60. Fundulus similis*			3										3	T
61. Notemigonus crysoleucas*											2		2	T
62. Carpiodes carpio*	1	1											2	T
63. Caranx hippos*							1				1		2	T
64. Chaetodipterus faber*									1	1			2	T
65. Astroscopus y-graecum*											2		2	T
66. Chasmodes bosquianus*										1	1		2	T
67. Gobionellus shufeldti				1		1							2	T
68. Sphoeroides parvus*									1			1	2	T
69. Rhinoptera bonasus*									1				1	T
70. Acipenser oxyrhynchus*	1												1	T
71. Polyodon spathula*						1							1	T
72. Adinia xenica	1												1	T
73. Fundulus chrysotus											1		1	T
74. Chaenobryttus gulosus												1	1	T
75. Monacanthus hispidus*											1		1	T

*Collected only in lake.

T(Trace Species): less than .1%.

Table 4. Relative abundance of fish species collected in Lake Pontchartrain Marsh in 1978

	Species	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total	Percent catch
1.	Cyprinodon variegatus	[illegible]	230	186	26	329	59	15	284	26	42	16	44	2411	11.4
2.	Anchoa mitchilli		2	4	175	20	139	480	134	266	126	619	217	2362	11.3
3.	Poecilia latipinna	5	432	58	13	795	5	8	396	101	143	134	150	2240	10.6
4.	Lucania parva	274	287	79	51	6	95	34	337	70	82	236	592	2143	10.2
5.	Brevoortia patronus		4	73	916	927	1	4	31	1	5	12	3	1984	9.4
6.	Menidia beryllina	71	544	292	305	13	62	156	39	87	42	45	93	1765	8.4
7.	Gambusia affinis	127	367	145	123	164	70	2	59	77	49	15	110	1258	6.0
8.	Lepomis punctatus	46	105	135	3	1	11	110	92	22	164	140	58	887	4.2
9.	Micropogonias undulatus	40	3	4	26	52	1	265	90	309	15	9		814	3.9
10.	Lepomis macrochirus	19	41	56	23	10	48	118	85		91	177	86	748	3.5
11.	Fundulus grandis	355	150	66	4	46	11	4	17	1	3	2	6	717	3.4
12.	Leiostomus xanthurus				4	57	25	57	38	427	39	10		657	3.1
13.	Heterandria formosa	17	93	9	68	26	4		5	5	52	48	160	487	2.3
14.	Lepomis microlophus	3	116	75	2	6	3	5	67	2	51	44	32	405	1.9
15.	Ictalurus punctatus	75	33	98	8	4	4	20	8	11	39	16	39	355	1.7
16.	Adinia xenica	257	12	27	3								16	315	1.5
17.	Ictalurus furcatus	1	1	102		1	10	7	39	43	52	6	7	270	1.3
18.	Mugil cephalus	7	173	11	13		7	6			12	8	13	250	
19.	Fundulus jenkinsi*	117		43									49	209	1.0
20.	Fundulus pulvereus	23	19	4	5	56	1		7	2			22	139	0.7
21.	Micropterus salmoides	1	3		2	1	29	29	4		36	10	11	126	0.6
22.	Lepisosteus oculatus		13	18	1	1	1	11			23	11	5	84	0.4
23.	Trinectes maculatus		3	10	5	5		1		2	54	3		83	0.4
24.	Syngnathus scovelli			1			6	1	2	5	5	8	15	43	0.2
25.	Cynoscion nebulosus							1	1	2	29	5		38	0.2
26.	Gobiosoma bosci	2	5		2		2	1	2	5	6	5	7	37	0.2
27.	Dorosoma petenense		23	1					1	1		3	7	36	0.2
28.	Dorosoma cepedianum	4	2	2	2		1				6	14	1	32	0.2
29.	Pomoxis nigromaculatus*				1		6	2	9	1	2	1	1	23	0.1
30.	Lepisosteus spatula		2	9	1	1	4				1	1		19	T
31.	Lepomis megalotis*							1			5	8	2	16	T
32.	Amia calva*							2			4	5	4	15	T
33.	Arius felis								1	12	2			15	T
34.	Chaenobryttus gulosus		1	6			1	7						15	T
35.	Elops saurus						12							12	T
36.	Microgobius gulosus				1		2	4		1	2	1		11	T
37.	Aplodinotus grunniens	7												7	T
38.	Cynoscion arenarius						2					5		7	T
39.	Paralichthys lethostigma	1	2	2				1						6	T
40.	Lagodon rhomboides							2			3			5	T
41.	Bairdiella chrysura										2	2		4	T
42.	Anguilla rostrata							3						3	T
43.	Strongylura marina							1		1		1		3	T
44.	Morone mississippiensis	2	1											3	T
45.	Cyprinus carpio*							2						2	T
46.	Ictalurus natalis*							2						2	T
47.	Pylodictis olivaris										1	1		2	T
48.	Labidesthes sicculus*										1	1		2	T
49.	Dasyatis sabina										1			1	T
50.	Lepisosteus osseus						1							1	T
51.	Alosa chrysochloris												1	1	T
52.	Fundulus chrysotus			1										1	T
53.	Morone chrysops*										1			1	T
54.	Centrarchus macropterus*						1							1	T
55.	Archosargus probatocephalus		1											1	T
56.	Pogonias cromis												1	1	T
57.	Gobionellus shufeldti				1									1	T
58.	Microgobius thalassinus*												1	1	T
59.	Lepomis macrochirus x Lepomis microlophus hybrid*		1											1	T

*Collected only in marsh.

[illegible]

Table 10. List of Fishes Reported or Collected from the Lake Pontchartrain Basin by Other Sources and Not Collected in the Present Study

Family and Species	Source
Freshwater Component	
Cyprinidae	
1. Notropis venustus - Blacktail Shiner	Suttkus et al. (1954e)
2. Opsopoeodus emiliae - Pugnose Minnow	Preliminary survey[1]
Catostomidae	
3. Ictiobus niger - Black Buffalo	Tarver and Savoie (1976)
Ictaluridae	
4. Ictalurus melas - Black Bullhead	Suttkus et al. (1954d)
Aphredoderidae	
5. Aphredoderus sayanus - Pirate Perch	Tarver and Savoie (1976)
Centrarchidae	
6. Elassoma zonatum - Pigmy Sunfish	Preliminary survey[1]
Marine Component	
Elopidae	
1. Megalops atlantica - Tarpon	Duffy (1975) Davis (1978) Suttkus et al. (1954d)
Ophichthidae	
2. Myrophis punctatus - Speckled Worm Eel	Suttkus et al. (1954d) Tarver and Savoie (1976) Pass study[2]
Clupeidae	
3. Harengula jaguana - Scaled Sardine (as H. pensacolae)	Suttkus et al. (1954d)
Synodontidae	
4. Synodus foetens - Inshore Lizardfish	Suttkus et al. (1954e) Tarver and Savoie (1976)
Batrachoididae	
5. Porichthys porosissimus - Midshipman	Suttkus et al. (1954f)
Gadidae	
6. Urophycis floridanus - Southern Hake	Suttkus et al. (1955a)
Exocoetidae	
7. Hyporhamphus unifasciatus - Halfbeak	Suttkus et al. (1954e)

[1] Species collected 10/77 to 12/77 as part of the preliminary survey for this lake study.

[2] Species collected in this project but only in the pass study.

Table 10. (Continued)

Family and Species	Source
Syngnathidae	
8. *Syngnathus floridae* - Dusky Pipefish	Tarver and Savoie (1976)
Percichthyidae	
9. *Morone saxatilis* - Striped Bass	Tarver and Savoie (1976)
Serranidae	
10. *Centropristis philadelphica* - Rock Sea Bass	Suttkus et al. (1954f)
Echeneidae	
11. *Echeneis naucrates* - Sharksucker	Suttkus et al. (1954d)
Carangidae	
12. *Chloroscombrus chrysurus* - Atlantic Bumper	Suttkus et al. (1954e)
13. *Hemicaranx amblyrhynchus* - Bluntnose Jack	Suttkus et al. (1954e)
14. *Vomer setapinnis* - Atlantic Moonfish	Davis et al. (1970) Suttkus et al. (1954e)
Gerreidae	
15. *Eucinostomus argenteus* - Spotfin Mojarra	Suttkus et al. (1954d)
Sciaenidae	
16. *Stellifer lanceolatus* - Star Drum	Suttkus et al. (1954d) Tarver and Savoie (1976)
Blenniidae	
17. *Hypsoblennius ionthas* - Freckled Blenny	Suttkus et al. (1955a)
Gobiidae	
18. *Gobioides broussonneti* - Violet Goby	Suttkus et al. (1954d)
19. *Gobionellus hastatus* - Sharptail Goby	Suttkus et al. (1954d) Pass study[2]
Trichiuridae	
20. *Trichiurus lepturus* - Atlantic Cutlassfish	Suttkus et al. (1954d) Davis et al. (1970)
Scombridae	
21. *Scomberomorus maculatus* - Spanish Mackerel	Suttkus et al. (1954d) Davis et al. (1970)
Stromateidae	
22. *Peprilus alepidotus* - Harvestfish	Suttkus et al. (1954e)
23. *Peprilus burti* - Gulf Butterfish	Suttkus et al. (1955)
Bothidae	
24. *Etropus crossotus* - Fringed Flounder	Suttkus et al. (1954e)
25. *Paralichthys albigutta* - Gulf Flounder	Tarver and Savoie (1976) Pass study[2]

[1] species collected 10/77 to 12/77 as part of the preliminary survey for this lake study.

[2] species collected in this project but only in the pass study.

Table 10. (Continued)

Family and Species	Source
Soleidae	
26. Achirus lineatus - Lined Sole	Suttkus et al. (1954d) Tarver and Savoie (1976) Preliminary survey[1]

[1]species collected 10/77 to 12/77 as part of the preliminary survey for this lake study.

[2]species collected in this project but only in the pass study.

Table 11. Most Abundant Species in Lake Pontchartrain, LA, for 1978

JANUARY

Species	Number	% of Catch
1. *Menidia beryllina*	281	35.4
2. *Anchoa mitchilli*	125	15.8
3. *Mugil cephalus*	121	15.3
4. *Micropogonias undulatus*	79	10.0
5. *Dorosoma cepedianum*	27	3.4
	633	79.9

FEBRUARY

Species	Number	% of Catch
1. *Menidia beryllina*	736	38.8
2. *Anchoa mitchilli*	525	27.6
3. *Micropogonias undulatus*	251	13.2
4. *Brevoortia patronus*	127	6.7
5. *Ictalurus furcatus*	47	2.5
	1686	88.8

MARCH

Species	Number	% of Catch
1. *Micropogonias undulatus*	716	23.3
2. *Brevoortia patronus*	685	22.3
3. *Anchoa mitchilli*	684	22.2
4. *Cyprinodon variegatus*	284	9.2
5. *Menidia beryllina*	220	7.2
	2589	84.2

APRIL

Species	Number	% of Catch
1. *Brevoortia patronus*	3419	51.5
2. *Anchoa mitchilli*	1187	17.9
3. *Micropogonias undulatus*	757	11.4
4. *Menidia beryllina*	590	8.9
5. *Leiostomus xanthurus*	260	3.9
	6213	93.6

Table 11. (Continued)

MAY

Species	Number	% of Catch
1. *Brevoortia patronus*	3950	61.5
2. *Anchoa mitchilli*	855	13.3
3. *Micropogonias undulatus*	831	12.9
4. *Menidia beryllina*	229	3.6
5. *Leiostomus xanthurus*	189	2.9

JUNE

Species	Number	% of Catch
1. *Anchoa mitchilli*	2019	33.6
2. *Micropogonias undulatus*	814	13.6
3. *Menidia beryllina*	731	12.2
4. *Cyprinodon variegatus*	356	5.9
5. *Fundulus grandis*	349	5.8

JULY

Species	Number	% of Catch
1. *Micropogonias undulatus*	3236	38.7
2. *Anchoa mitchilli*	2519	30.1
3. *Menidia beryllina*	854	10.2
4. *Leiostomus xanthurus*	296	3.5
5. *Syngnathus scovelli*	246	2.9
	7151	85.4

AUGUST

Species	Number	% of Catch
1. *Anchoa mitchilli*	3155	44.8
2. *Micropogonias undulatus*	799	11.3
3. *Menidia beryllina*	676	9.6
4. *Cyprinodon variegatus*	514	7.3
5. *Syngnathus scovelli*	416	5.9
	5560	78.9

Table 11. (Continued)

SEPTEMBER

Species	Number	% of Catch
1. *Anchoa mitchilli*	2797	42.1
2. *Micropogonias undulatus*	1821	27.4
3. *Menidia beryllina*	674	10.1
4. *Syngnathus scovelli*	413	6.2
5. *Arius felis*	215	3.2
	5920	89.0

OCTOBER

Species	Number	% of Catch
1. *Anchoa mitchilli*	3757	60.6
2. *Micropogonias undulatus*	543	8.8
3. *Syngnathus scovelli*	534	8.6
4. *Arius felis*	428	6.9
5. *Menidia beryllina*	245	4.0
	5507	88.9

NOVEMBER

Species	Number	% of Catch
1. *Anchoa mitchilli*	3909	63.5
2. *Micropogonias undulatus*	793	12.9
3. *Menidia beryllina*	577	9.4
4. *Syngnathus scovelli*	350	5.7
5. *Gobiosoma bosci*	76	1.2
	5705	92.7

DECEMBER

Species	Number	% of Catch
1. *Micropogonias undulatus*	727	21.5
2. *Anchoa mitchilli*	535	15.9
3. *Cyprinodon variegatus*	350	10.4
4. *Menidia beryllina*	308	9.1
5. *Poecilia latipinna*	297	8.8
	2217	65.7

Table 11. (Continued)

1978		Number	% of Catch	Cumulative
1.	Anchoa mitchilli	22067	35.2	
2.	Micropogonias undulatus	11367	18.2	
3.	Brevoortia patronus	9076	14.5	
4.	Menidia beryllina	6121	9.8	
5.	Syngnathus scovelli	2219	3.5	81.2
6.	Cyprinodon variegatus	1644	2.6	
7.	Leiostomus xanthurus	1379	2.2	
8.	Arius felis	1109	1.8	
9.	Lucania parva	938	1.5	
10.	Fundulus grandis	723	1.2	90.5
11.	Mugil cephalus	688	1.1	
12.	Cynoscion arenarius	570	0.9	
13.	Poecilia latipinna	531	0.8	94.9
14.	Gambusia affinis	520	0.8	
15.	Gobiosoma bosci	470	0.8	
16.	Trinectes maculatus	357	0.6	
17.	Cynoscion nebulosus	308	0.5	
18.	Ictalurus furcatus	270	0.4	
19.	Alosa chrysochloris	213	0.3	
20.	Membras martinica	195	0.3	97.0

Table 12. Seasonal Faunal Similarity of Lake Pontchartrain, LA, and Surrounding Marsh Fishes, 1978

LAKE

	Winter	Spring	Summer	Fall
Winter		33 sp. - 44%	33 sp. - 44%	34 sp. - 45%
Spring			40 sp. - 53%	41 sp. - 55%
Summer				47 sp. - 63%
W/Sp/Su	←	1 sp. - 1.3%	→	
W/Sp/Su/F	←	27 sp. - 36%		→
Sp/Su/F		←	9 sp. - 12%	→
W/Sp/F	← 3 sp. - 4%	→		
W/Su/F	←→		← 3 sp. - 4%	→

MARSH

	Winter	Spring	Summer	Fall
Winter		28 sp. - 48%	29 sp. - 50%	28 sp. - 48%
Spring			30 sp. - 52%	28 sp. - 48%
Summer				35 sp. - 60%
W/Sp/Su	←	2 sp. - 3%	→	
W/Sp/Su/F	←	26 sp. - 45%		→
Sp/Su/F		←	2 sp. - 3%	→
W/Sp/F	← NONE	→		←→
W/Su/F	←→		← 2 sp. - 3%	→

Note: winter = Dec., Jan., and Feb.; spring = Mar., Apr., and May; summer = June, July, and Aug.; fall = Sept., Oct., and Nov.

Table 13. Classification of 20 Most Abundant Fish Species in Lake Pontchartrain and Surrounding Marsh by Overall Habitat Preference (Based on 1978 Data)

	Open lake	Grassbeds	Beach	Marsh
Anchoa mitchilli	1		2	2
Micropogonias undulatus	1			
Brevoortia patronus	1		2j	2j
Menidia beryllina		2	1	2
Cyprinodon variegatus			2	1
Lucania parva		2		1
Poecilia latipinna		2		1
Syngnathus scovelli		1		
Leiostomus xanthurus	1	2j		
Gambusia affinis				1
Fundulus grandis			1	2
Arius felis	1		2j	
Mugil cephalus	1		2j	
Lepomis punctatus		2		1
Lepomis macrochirus		2		1
Cynoscion arenarius	1			
Ictalurus furcatus	1			
Lepomis microlophus		2		1
Heterandria formosa				1
Gobiosoma bosci		1		

1 = primary habitat of adults.
2 = secondary habitat.

Table 14. Number of Species (S) of Demersal Fish Collected by Trawl in Lake Pontchartrain, 1978

	STATIONS 1	2	3	4	5	6	7	8	9	10	11	12	STA $\bar{X}$	Mdn	S	S^2	CV
JAN	3	4	2	5	7	4	3	6	4	4	M	5	4.27	4.0	1.42	2.02	33.3
FEB	7	5	7	4	7	3	2	5	4	4	6	6	5.00	5.0	1.65	2.72	33.0
MAR	4	4	1	5	5	5	5	5	4	5	5	1	4.08	5.0	1.51	2.28	37.0
APR	2	4	5	5	3	3	3	3	3	1	4	5	3.42	3.0	1.24	1.54	36.3
MAY	6	5	6	6	7	5	6	1	5	2	3	2	4.50	5.0	1.98	3.92	44.0
JUN	3	4	1	6	1	3	6	5	4	3	0	4	3.64	3.5	1.69	2.86	46.4
JUL	3	3	6	7	5	6	7	7	7	7	7	7	6.00	7.0	1.54	2.37	25.7
AUG	4	5	8	6	5	6	5	4	7	4	3	3	5.00	5.0	1.54	2.37	30.8
SEP	4	6	1	10	7	7	8	8	8	4	7	3	6.08	7.0	2.57	6.60	42.3
OCT	5	5	5	4	8	6	7	1	7	7	4	4	5.25	5.0	1.91	3.66	36.4
NOV	4	5	2	7	6	3	8	1	4	4	2	4	4.17	4.0	2.08	4.33	49.5
DEC	8	8	2	2	6	4	2	6	9	5	6	2	5.00	5.5	2.59	6.73	51.8
YEAR $\bar{X}$	4.42	4.83	3.83	5.58	5.58	4.58	5.17	4.33	5.50	4.17	4.27	3.83					
Mdn	4.0	5.0	3.5	5.5	6.0	4.5	5.5	5.0	4.5	4.0	4.0	4.0					
S	1.78	1.27	2.59	1.98	1.98	1.44	2.21	2.39	1.98	1.75	2.20	1.75					
S^2	3.17	1.61	6.70	3.90	3.90	2.08	4.88	5.70	3.91	3.06	4.82	3.06					
CV	40.3	26.3	67.6	35.5	35.5	31.4	42.7	55.2	36.0	42.0	51.5	45.7					

M = station missing

Table 15. Index of Occurrence (Based on Stations Where Species were Captured, i.e. 1.00 = All Stations) for Selected Species of Lake and Marsh Fishes, 1978*

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	MIN	MAX	$\bar{x}$	Mdn	S	S^2	CV
Anchoa mitchilli	.40	.75	.75	.81	.81	.82	.94	.88	1.00	.71	1.00	.94	.40	1.00	.92	.82	.16	.03	19.51
Micropogonias undulatus	.60	.88	.63	.94	.81	.65	.76	.71	.75	.82	.88	.59	.59	.94	.76	.76	.12	.01	15.79
Brevoortia patronus	.33	.56	.63	.63	.88	.47	.59	.41	.56	.59	.35	.41	.33	88	.54	.56	.15	.02	27.78
Menidia beryllina	.60	.56	.50	.50	.38	.53	.59	.53	.56	.47	.47	.53	.38	.60	.52	.53	.06	.01	11.54
Cyprinodon variegatus	.40	.50	.38	.31	.25	.41	.24	.35	.19	.18	.29	.41	.18	.50	.33	.33	.10	.01	30.30
Lucania parva	.47	.44	.38	.25	.13	.41	.41	.35	.31	.41	.35	.35	.13	.47	.36	.37	.09	.01	25.00
Poecilia latipinna	.13	.06	.13	.25	.13	.24	.06	.24	.19	.18	.12	.24	.06	.25	.17	.16	.07	.01	41.18
Syngnathus scovelli	.07	.06	.13	.13	.00	.24	.29	.29	.31	.41	.41	.41	.00	.41	.24	.27	.15	.02	62.50
Leiostomus xanthurus	.00	.00	.25	.50	.63	.41	.76	.76	.63	.47	.59	.35	.00	.76	.45	.49	.26	.07	57.78
Gambusia affinis	.20	.38	.38	.31	.19	.18	.12	.24	.19	.12	.12	.18	.12	.38	.23	.20	.09	.01	40.39
Fundulus grandis	.27	.38	.25	.38	.25	.35	.24	.24	.19	.18	.18	.18	.18	.38	.27	.25	.08	.01	27.81
Arius felis	.00	.00	.00	.19	.44	.29	.53	.71	.63	.65	.24	.00	.00	.71	.31	.27	.28	.08	89.52
Mugil cephalus	.60	.56	.38	.38	.31	.35	.29	.18	.13	.18	.41	.24	.12	.60	.34	.33	.15	.02	42.76
Lepomis punctatus	.20	.19	.19	.06	.06	.18	.24	.24	.25	.35	.29	.29	.06	.35	.21	.22	.09	.01	41.24
Lepomis macrochirus	.20	.19	.19	.13	.06	.18	.29	.35	.19	.24	.29	.24	.06	.35	.22	.20	.08	.01	35.00
Cynoscion arenarius	.07	.00	.00	.00	.06	.29	.59	.35	.50	.47	.53	.18	.00	.59	.26	.24	.23	.05	88.12
Ictalurus furcatus	.40	.63	.25	.25	.44	.12	.12	.12	.25	.29	.06	.41	.06	.63	.29	.25	.17	.03	57.66
Lepomis microlophus	.13	.19	.19	.13	.19	.18	.12	.29	.19	.24	.29	.18	.12	.29	.20	.19	.06	.01	28.05
Heterandria formosa	.13	.13	.06	.19	.19	.18	.00	.18	.13	.12	.06	.00	.00	.19	.12	.13	.07	.01	57.75
Gobiosoma bosci	.07	.06	.13	.13	.00	.18	.24	.24	.31	.18	.29	.29	.00	.29	.18	.16	.10	.01	56.06

*JAN-MAY = 16 stations, JUN-DEC = 17 stations.

Table 16. Monthly Catch Results for Lake Pontchartrain, LA, 1978

MONTH = 1

STAT	NUMBER OF SPECIMNS	NUMBER OF SPP.	NUMBER OF SPP. PER EACH GEAR TYPE				TIME FISHED FOR EACH GEAR TYPE				TOTAL NUMBER OF FISH				CATCH / EFFORT (FISH/HOUR)			
			TRAWL	SEINE	STNT	SHKR	TRAWL	SEINE	STNT	SHKR	TRAWL	SEINE	STNT	SHKR	TRAWL	SEINE	STNT	SHKR
1	15	5	7	0	2	0	0.25	0.0	8.00	0.0	12.	0.	3.	0.	48.00	0.0	0.38	0.0
2	45	10	4	6	0	0	0.25	1.00	0.0	0.0	14.	31.	0.	0.	56.00	31.00	0.0	0.0
3	139	8	2	6	0	0	0.25	0.50	0.0	0.0	2.	137.	0.	0.	8.00	274.00	0.0	0.0
4	231	16	5	4	10	0	0.25	0.50	10.50	0.0	27.	160.	44.	0.	108.00	320.00	4.19	0.0
5	39	7	7	0	0	0	0.50	0.0	0.0	0.0	39.	0.	0.	0.	78.00	0.0	0.0	0.0
6	212	14	4	9	5	0	0.25	0.50	10.10	0.0	51.	154.	7.	0.	204.00	308.00	0.69	0.0
7	51	3	3	0	0	0	0.50	0.0	0.0	0.0	51.	0.	0.	0.	102.00	0.0	0.0	0.0
8	140	11	6	6	3	0	0.50	0.67	4.58	0.0	53.	79.	8.	0.	106.00	118.50	1.75	0.0
9	27	4	4	0	0	0	0.50	0.0	0.0	0.0	27.	0.	0.	0.	54.00	0.0	0.0	0.0
10	9	4	4	0	0	0	0.50	0.0	0.0	0.0	9.	0.	0.	0.	18.00	0.0	0.0	0.0
11	0	0	0	0	0	0	0.0	0.0	0.0	0.0	0.	0.	0.	0.	0.0	0.0	0.0	0.0
12	7	5	5	0	0	0	0.33	0.0	0.0	0.0	7.	0.	0.	0.	21.00	0.0	0.0	0.0
SUM	915.	87.	47.0	31.0	20.0	0.0	4.08	3.17	33.18	0.0	292.	561.	62.	0.	803.00	1051.50	7.01	0.0
MEAN	83.2	7.9	4.27	6.20	5.00	0.0	0.37	0.63	8.29	0.0	27.	112.	16.	0.	73.00	210.30	1.75	0.0
STD	82.67	4.35	1.42	1.79	3.56	0.0	0.13	0.22	2.71	0.0	19.	56.	19.	0.	56.19	128.66	1.73	0.0

STNT = Stationary Net (Gill and/or Trammel)
SHKR = Shocker

Table 16. (Continued)

MONTH = 2

STAT	NUMBER OF SPECIMENS	NUMBER OF SPP.	NUMBER OF SPP. PER EACH GEAR TYPE: TRAWL	SEINE	STNT	SHKR	TIME FISHED FOR EACH GEAR TYPE: TRAWL	SEINE	STNT	SHKR	TOTAL NUMBER OF FISH: TRAWL	SEINE	STNT	SHKR	CATCH / EFFORT (FISH/HOUR): TRAWL	SEINE	STNT	SHKR
1	20	9	7	0	4	0	0.33	0.0	12.20	0.0	16.	0.	4.	0.	48.00	0.0	0.33	0.0
2	103	9	5	4	0	0	0.50	0.50	0.0	0.0	84.	19.	0.	0.	168.00	38.00	0.0	0.0
3	853	17	7	10	0	0	0.50	0.33	0.0	0.0	29.	824.	0.	0.	58.00	2472.00	0.0	0.0
4	584	16	4	5	8	0	0.50	0.50	9.25	0.0	80.	462.	42.	0.	160.00	924.00	4.54	0.0
5	158	7	7	0	0	0	0.50	0.0	0.0	0.0	158.	0.	0.	0.	316.00	0.0	0.0	0.0
6	149	11	3	5	4	0	0.50	0.58	10.50	0.0	14.	127.	8.	0.	28.00	217.70	0.76	0.0
7	47	2	2	0	0	0	0.50	0.0	0.0	0.0	47.	0.	0.	0.	94.00	0.0	0.0	0.0
8	291	10	5	7	6	0	0.50	0.50	10.00	0.0	161.	106.	24.	0.	322.00	212.00	2.40	0.0
9	19	4	4	0	0	0	0.50	0.0	0.0	0.0	19.	0.	0.	0.	38.00	0.0	0.0	0.0
10	325	13	4	9	2	0	0.50	0.75	9.08	0.0	51.	267.	7.	0.	102.00	356.00	0.77	0.0
11	20	6	6	0	0	0	0.50	0.0	0.0	0.0	20.	0.	0.	0.	40.00	0.0	0.0	0.0
12	154	6	6	0	0	0	0.50	0.0	0.0	0.0	154.	0.	0.	0.	308.00	0.0	0.0	0.0
SUM	2723.	110.	60.0	40.0	24.0	0.0	5.83	3.16	51.03	0.0	833.	1805.	85.	0.	1682.00	4219.70	8.80	0.0
MEAN	226.9	9.2	5.00	6.67	4.80	0.0	0.49	0.53	10.21	0.0	69.	301.	17.	0.	140.17	703.28	1.76	0.0
STD	256.89	4.57	1.65	2.42	2.28	0.0	0.05	0.14	1.25	0.0	58.	299.	16.	0.	114.89	918.42	1.74	0.0

STNT = Stationary Net (Gill and/or Trammel)
SHKR = Shocker

Table 16. (Continued)

MONTH = 3

STAT	NUMBER OF SPECIMNS	NUMBER OF SPP.	NUMBER OF SPP. FOR EACH GEAR TYPE				TIME FISHED FOR EACH GEAR TYPE				TOTAL NUMBER OF FISH				CATCH / EFFORT (FISH/HOUR)			
			TRAWL	SEINE	STNT	SHKR	TRAWL	SEINE	STNT	SHKR	TRAWL	SEINE	STNT	SHKR	TRAWL	SEINE	STNT	SHKR
1	58	5	4	0	1	0	0.50	0.0	8.00	0.0	57.	0.	1.	0.	114.00	0.0	0.13	0.0
2	628	8	4	8	0	0	0.50	0.50	0.0	0.0	120.	508.	0.	0.	240.00	1016.00	0.0	0.0
3	5	1	1	0	0	0	0.50	0.0	0.0	0.0	5.	0.	0.	0.	10.00	0.0	0.0	0.0
4	1556	17	5	11	7	0	0.50	0.50	33.00	0.0	79.	1413.	64.	0.	158.00	2826.00	1.94	0.0
5	124	5	5	0	0	0	0.50	0.0	0.0	0.0	124.	0.	0.	0.	248.00	0.0	0.0	0.0
6	875	18	5	12	5	0	0.50	0.50	8.83	0.0	240.	625.	10.	0.	480.00	1250.00	1.13	0.0
7	30	5	5	0	0	0	0.50	0.0	0.0	0.0	30.	0.	0.	0.	60.00	0.0	0.0	0.0
8	379	16	5	9	8	0	0.50	0.50	8.00	0.0	78.	271.	30.	0.	156.00	542.00	3.75	0.0
9	41	4	4	0	0	0	0.50	0.0	0.0	0.0	41.	0.	0.	0.	82.00	0.0	0.0	0.0
10	195	5	5	0	0	0	0.50	0.0	0.0	0.0	195.	0.	0.	0.	390.00	0.0	0.0	0.0
11	193	5	5	0	0	0	0.50	0.0	0.0	0.0	193.	0.	0.	0.	386.00	0.0	0.0	0.0
12	1	1	1	0	0	0	0.50	0.0	0.0	0.0	1.	0.	0.	0.	2.00	0.0	0.0	0.0
SUM	4085.	90.	49.0	40.0	21.0	0.0	6.00	2.00	57.83	0.0	1163.	2817.	105.	0.	2326.00	5634.00	6.95	0.0
MEAN	340.4	7.5	4.08	10.00	5.25	0.0	0.50	0.50	14.46	0.0	97.	704.	26.	0.	193.83	1408.50	1.74	0.0
STD	470.09	6.04	1.51	1.83	3.10	0.0	0.0	0.0	12.37	0.0	79.	495.	28.	0.	157.36	989.83	1.53	0.0

STNT = Stationary Net (Gill and/or Trammel)
SHKR = Shocker

Table 16. (Continued)

MONTH = 4

STAT	NUMBER OF SPECIMNS	NUMBER OF SPP.	NUMBER OF SPP. FOR EACH GEAR TYPE				TIME FISHED FOR EACH GEAR TYPE				TOTAL NUMBER OF FISH				CATCH / EFFORT (FISH/HOUR)			
			TRAWL	SEINE	STNT	SHKR	TRAWL	SEINE	STNT	SHKR	TRAWL	SEINE	STNT	SHKR	TRAWL	SEINE	STNT	SHKR
1	55	8	2	0	7	0	0.50	0.0	5.67	0.0	45.	0.	4.	0.	90.00	0.0	0.71	0.0
2	774	15	4	11	0	0	0.50	0.50	0.0	0.0	139.	635.	0.	0.	278.00	1270.00	0.0	0.0
3	243	5	5	0	0	0	0.50	0.0	0.0	0.0	243.	0.	0.	0.	486.00	0.0	0.0	0.0
4	528	18	5	6	12	0	0.50	0.50	13.50	0.0	176.	292.	60.	0.	352.00	584.00	4.44	0.0
5	25	3	3	0	0	0	0.50	0.0	0.0	0.0	25.	0.	0.	0.	50.00	0.0	0.0	0.0
6	745	19	3	11	11	0	0.50	0.50	5.00	0.0	182.	514.	49.	0.	364.0	1028.00	9.80	0.0
7	96	3	3	0	0	0	0.50	0.0	0.0	0.0	96.	0.	0.	0.	192.00	0.0	0.0	0.0
8	1091	11	3	9	6	0	0.50	0.50	4.25	0.0	57.	928.	106.	0.	114.00	1856.00	24.94	0.0
9	77	3	3	0	0	0	0.50	0.0	0.0	0.0	77.	0.	0.	0.	154.00	0.0	0.0	0.0
10	2862	16	1	12	8	0	0.50	0.58	10.60	0.0	80.	2742.	40.	0.	160.00	4700.60	3.78	0.0
11	55	4	4	0	0	0	0.50	0.0	0.0	0.0	55.	0.	0.	0.	110.00	0.0	0.0	0.0
12	90	5	5	0	0	0	0.50	0.0	0.0	0.0	90.	0.	0.	0.	180.00	0.0	0.0	0.0
SUM	6641.	110.	41.0	49.0	44.0	0.0	5.50	2.58	39.02	0.0	1083.	5111.	259.	0.	2166.00	9438.60	43.67	0.0
MEAN	553.4	9.2	3.42	9.80	8.80	0.0	0.50	0.52	7.80	0.0	98.	1022.	52.	0.	196.91	1887.72	8.73	0.0
STD	810.61	6.29	1.24	2.39	2.59	0.0	0.0	0.04	4.04	0.0	64.	988.	37.	0.	128.51	1638.12	9.63	0.0

STNT = Stationary Net (Gill and/or Trammel)
SHKR = Shocker

Table 16. (Continued)

MONTH = 5

STAT	NUMBER OF SPECIMENS	NUMBER OF SPP.	NUMBER OF SPP. FOR EACH GEAR TYPE				TIME FISHED FOR EACH GEAR TYPE				TOTAL NUMBER OF FISH				CATCH / EFFORT (FISH/HOUR)			
			TRAWL	SEINE	STNT	SHKR	TRAWL	SEINE	STNT	SHKR	TRAWL	SEINE	STNT	SHKR	TRAWL	SEINE	STNT	SHKR
1	183	10	6	0	7	0	0.50	0.0	5.50	0.0	155.	0.	28.	0.	310.00	0.0	5.09	0.0
2	1552	15	5	13	0	0	0.50	1.00	0.0	0.0	110.	1442.	0.	0.	220.00	1442.00	0.0	0.0
3	24	6	6	0	0	0	0.50	0.0	0.0	0.0	24.	0.	0.	0.	48.00	0.0	0.0	0.0
4	2058	20	6	18	8	0	0.50	1.00	4.00	0.0	696.	1302.	60.	0.	1392.00	1302.00	15.00	0.0
5	176	7	7	0	0	0	0.50	0.0	0.0	0.0	176.	0.	0.	0.	352.00	0.0	0.0	0.0
6	368	17	5	13	6	0	0.50	0.75	7.00	0.0	133.	215.	20.	0.	266.00	286.70	2.86	0.0
7	103	6	6	0	0	0	0.50	0.0	0.0	0.0	103.	0.	0.	0.	206.00	0.0	0.0	0.0
8	435	10	1	5	7	0	0.50	0.50	4.00	0.0	82.	314.	39.	0.	164.00	628.00	9.75	0.0
9	14	5	5	0	0	0	0.50	0.0	0.0	0.0	14.	0.	0.	0.	28.00	0.0	0.0	0.0
10	1447	16	2	12	5	0	0.50	0.67	3.00	0.0	198.	1224.	25.	0.	396.00	1836.00	8.33	0.0
11	39	3	3	0	0	0	0.50	0.0	0.0	0.0	39.	0.	0.	0.	78.00	0.0	0.0	0.0
12	16	2	2	0	0	0	0.50	0.0	0.0	0.0	16.	0.	0.	0.	32.00	0.0	0.0	0.0
SUM	6415.	117.	54.0	61.0	33.0	0.0	6.00	3.92	23.50	0.0	1746.	4497.	172.	0.	3492.00	5494.70	41.03	0.0
MEAN	534.6	9.8	4.50	12.20	6.60	0.0	0.50	0.78	4.70	0.0	146.	899.	34.	0.	291.00	1098.94	8.21	0.0
STD	720.53	5.94	1.98	4.66	1.14	0.0	0.0	0.22	1.57	0.0	184.	586.	16.	0.	368.90	629.21	4.66	0.0

STNT = Stationary Net (Gill and/or Trammel)
SHKR = Shocker

Table 16. (Continued)

MONTH = 6

STAT	NUMBER OF SPECIMNS	NUMBER OF SPP.	NUMBER OF SPP. FOR EACH GEAR TYPE				TIME FISHED FOR EACH GEAR TYPE				TOTAL NUMBER OF FISH				CATCH / EFFORT (FISH/HOUR)			
			TRAWL	SEINE	STNT	SHKR	TRAWL	SEINE	STNT	SHKR	TRAWL	SEINE	STNT	SHKR	TRAWL	SEINE	STNT	SHKR
1	304	10	3	0	8	0	0.50	0.0	5.00	0.0	239.	0.	65.	0.	478.00	0.0	13.00	0.0
2	1236	13	4	13	0	0	0.50	0.67	0.0	0.0	300.	936.	0.	0.	600.00	1404.00	0.0	0.0
3	284	1	1	0	0	0	0.50	0.0	0.0	0.0	284.	0.	0.	0.	568.00	0.0	0.0	0.0
4	1483	27	6	23	8	0	0.50	1.33	4.75	0.0	131.	1298.	54.	0.	262.00	973.50	11.37	0.0
5	53	1	1	0	0	0	0.47	0.0	0.0	0.0	53.	0.	0.	0.	114.00	0.0	0.0	0.0
6	330	19	3	15	5	0	0.50	0.75	5.08	0.0	74.	244.	12.	0.	148.00	325.30	2.36	0.0
7	94	6	6	0	0	0	0.50	0.0	0.0	0.0	94.	0.	0.	0.	188.00	0.0	0.0	0.0
8	260	14	5	7	7	0	0.50	0.75	4.25	0.0	42.	181.	37.	0.	84.00	241.30	8.71	0.0
9	66	4	4	0	0	0	0.50	0.0	0.0	0.0	66.	0.	0.	0.	132.00	0.0	0.0	0.0
10	1119	20	3	15	9	0	0.50	0.75	4.33	0.0	134.	908.	77.	0.	268.00	1210.70	17.77	0.0
11	0	0	0	0	0	0	0.50	0.0	0.0	0.0	0.	0.	0.	0.	0.0	0.0	0.0	0.0
12	179	4	4	0	0	0	0.50	0.0	0.0	0.0	179.	0.	0.	0.	358.00	0.0	0.0	0.0
17	571	18	0	18	0	0	0.0	0.50	0.0	0.0	0.	571.	0.	0.	0.0	1142.00	0.0	0.0
SUM	5979.	137.	40.0	91.0	37.0	0.0	5.97	4.75	23.41	0.0	1596.	4138.	245.	0.	3200.00	5296.80	53.21	0.0
MEAN	498.2	11.4	3.64	15.17	7.40	0.0	0.50	0.79	4.68	0.0	145.	690.	49.	0.	290.91	882.80	10.64	0.0
STD	497.61	8.45	1.69	5.31	1.52	0.0	0.01	0.28	0.38	0.0	93.	436.	25.	0.	165.35	485.16	5.68	0.0

STNT = Stationary Net (Gill and/or Trammel)
SHKR = Shocker

Table 16. (Continued)

MONTH = 7

STAT	NUMBER OF SPECIMENS	NUMBER OF SPP.	NUMBER OF SPP. FOR EACH GEAR TYPE				TIME FISHED FOR EACH GEAR TYPE				TOTAL NUMBER OF FISH				CATCH / EFFORT (FISH/HOUR)			
			TRAWL	SEINE	STNT	SHKR	TRAWL	SEINE	STNT	SHKR	TRAWL	SEINE	STNT	SHKR	TRAWL	SEINE	STNT	SHKR
1	120	10	3	0	7	0	0.50	0.0	6.50	0.0	37.	0.	83.	0.	74.00	0.0	12.77	0.0
2	193	8	3	7	0	0	0.50	0.33	0.0	0.0	74.	119.	0.	0.	148.00	357.00	0.0	0.0
3	730	6	6	0	0	0	0.50	0.0	0.0	0.0	730.	0.	0.	0.	1460.00	0.0	0.0	0.0
4	1235	28	7	24	6	0	0.50	1.00	4.33	0.0	384.	800.	38.	0.	768.00	800.00	8.77	0.0
5	454	5	5	0	0	0	0.50	0.0	0.0	0.0	454.	0.	0.	0.	908.00	0.0	0.0	0.0
6	810	23	6	18	5	0	0.50	0.83	6.17	0.0	558.	235.	17.	0.	1116.00	282.00	2.76	0.0
7	236	7	7	0	0	0	0.50	0.0	0.0	0.0	236.	0.	0.	0.	472.00	0.0	0.0	0.0
8	463	15	7	8	1	0	0.50	0.50	3.83	0.0	214.	248.	1.	0.	428.00	456.00	0.26	0.0
9	456	7	7	0	0	0	0.50	0.0	0.0	0.0	456.	0.	0.	0.	912.00	0.0	0.0	0.0
10	1730	18	7	10	9	0	0.50	0.50	4.00	0.0	735.	968.	27.	0.	1470.00	1936.00	6.75	0.0
11	671	7	7	0	0	0	0.50	0.0	0.0	0.0	671.	0.	0.	0.	1342.00	0.0	0.0	0.0
12	706	7	7	0	0	0	1.00	0.0	0.0	0.0	706.	0.	0.	0.	706.00	0.0	0.0	0.0
17	558	11	0	11	0	0	0.0	0.50	0.0	0.0	0.	558.	0.	0.	0.0	1116.00	0.0	0.0
SUM	8362.	152.	72.0	78.0	28.0	0.0	6.50	3.66	24.83	0.0	5255.	2928.	166.	0.	9804.00	4987.00	31.31	0.0
MEAN	643.2	11.7	6.00	13.00	5.60	0.0	0.54	0.61	4.97	0.0	438.	488.	33.	0.	817.00	831.17	6.26	0.0
STD	440.10	7.23	1.54	6.63	2.97	0.0	0.14	0.25	1.27	0.0	253.	344.	31.	0.	477.39	623.14	4.93	0.0

STNT = Stationary Net (Gill and/or Trammel)
SHKR = Shocker

Table 16. (Continued)

MONTH = 8

STAT	NUMBER OF SPECIMENS	NUMBER OF SPP.	NUMBER OF SPP. FOR EACH GEAR TYPE				TIME FISHED FOR EACH GEAR TYPE				TOTAL NUMBER OF FISH				CATCH / EFFORT (FISH/HOUR)			
			TRAWL	SEINE	STNT	SHKR	TRAWL	SEINE	STNT	SHKR	TRAWL	SEINE	STNT	SHKR	TRAWL	SEINE	STNT	SHKR
1	198	8	4	0	5	0	0.50	0.0	6.00	0.0	150.	0.	48.	0.	300.00	0.0	8.00	0.0
2	1216	17	5	16	0	0	0.50	0.50	0.0	0.0	186.	1030.	0.	0.	372.00	2060.00	0.0	0.0
3	338	8	8	0	0	0	0.50	0.0	0.0	0.0	338.	0.	0.	0.	676.00	0.0	0.0	0.0
4	1274	25	6	19	5	0	0.50	1.58	4.83	0.0	345.	879.	50.	0.	690.00	555.20	10.34	0.0
5	218	5	5	0	0	0	0.50	0.0	0.0	0.0	218.	0.	0.	0.	436.00	0.0	0.0	0.0
6	565	27	6	22	9	0	0.50	0.92	4.08	0.0	160.	391.	14.	0.	320.00	426.50	3.43	0.0
7	115	5	5	0	0	0	0.50	0.0	0.0	0.0	115.	0.	0.	0.	230.00	0.0	0.0	0.0
8	367	13	4	11	4	0	0.50	0.50	4.08	0.0	236.	119.	12.	0.	472.00	238.00	2.94	0.0
9	640	7	7	0	0	0	0.50	0.0	0.0	0.0	640.	0.	0.	0.	1280.00	0.0	0.0	0.0
10	1286	13	4	10	4	0	0.50	0.42	4.00	0.0	706.	566.	14.	0.	1412.00	1358.40	3.50	0.0
11	131	3	3	0	0	0	0.50	0.0	0.0	0.0	131.	0.	0.	0.	262.00	0.0	0.0	0.0
12	216	3	3	0	0	0	0.50	0.0	0.0	0.0	216.	0.	0.	0.	432.00	0.0	0.0	0.0
17	298	15	0	15	0	0	0.0	0.50	0.0	0.0	0.	298.	0.	0.	0.0	596.00	0.0	0.0
SUM	6862.	149.	60.0	93.0	27.0	0.0	6.00	4.42	22.99	0.0	3441.	3283.	138.	0.	6882.00	5234.10	28.21	0.0
MEAN	527.8	11.5	5.00	15.50	5.40	0.0	0.50	0.74	4.60	0.0	287.	547.	28.	0.	573.50	872.35	5.64	0.0
STD	443.83	7.87	1.54	4.59	2.07	0.0	0.0	0.45	0.85	0.0	195.	350.	20.	0.	389.66	656.40	3.33	0.0

STNT = Stationary Net (Gill and/or Trammel)
SHKR = Shocker

Table 16. (Continued)

MONTH = 9

STAT	NUMBER OF SPECIMENS	NUMBER OF SPP.	NUMBER OF SPP. FOR EACH GEAR TYPE				TIME FISHED FOR EACH GEAR TYPE				TOTAL NUMBER OF FISH				CATCH / EFFORT (FISH/HOUR)			
			TRAWL	SEINE	STNT	SHKR	TRAWL	SEINE	STNT	SHKR	TRAWL	SEINE	STNT	SHKR	TRAWL	SEINE	STNT	SHKR
1	410	11	4	0	8	0	0.50	0.0	13.30	0.0	380.	0.	30.	0.	760.00	0.0	2.25	0.0
2	915	14	6	11	0	0	0.50	0.50	0.0	0.0	318.	597.	0.	0.	636.00	1194.00	0.0	0.0
3	173	1	1	0	0	0	0.50	0.0	0.0	0.0	173.	0.	0.	0.	346.00	0.0	0.0	0.0
4	1060	28	10	20	5	0	0.50	1.17	4.00	0.0	455.	577.	28.	0.	910.00	494.60	7.00	0.0
5	247	7	7	0	0	0	0.50	0.0	0.0	0.0	247.	0.	0.	0.	494.00	0.0	0.0	0.0
6	631	22	7	13	7	0	0.50	0.58	5.00	0.0	396.	214.	21.	0.	792.00	366.90	4.20	0.0
7	220	8	8	0	0	0	0.50	0.0	0.0	0.0	220.	0.	0.	0.	440.00	0.0	0.0	0.0
8	332	16	8	9	4	0	0.50	0.50	4.50	0.0	211.	115.	6.	0.	422.00	230.00	1.33	0.0
9	1052	8	8	0	0	0	0.50	0.0	0.0	0.0	1052.	0.	0.	0.	2104.00	0.0	0.0	0.0
10	756	11	4	9	2	0	0.50	0.50	5.00	0.0	254.	497.	5.	0.	508.00	994.00	1.00	0.0
11	447	7	7	0	0	0	0.50	0.0	0.0	0.0	447.	0.	0.	0.	894.00	0.0	0.0	0.0
12	254	3	3	0	0	0	0.50	0.0	0.0	0.0	254.	0.	0.	0.	508.00	0.0	0.0	0.0
17	143	14	0	14	0	0	0.0	0.75	0.0	0.0	0.	143.	0.	0.	0.0	190.70	0.0	0.0
SUM	6640.	150.	73.0	76.0	26.0	0.0	6.00	4.00	31.80	0.0	4407.	2143.	90.	0.	8814.00	3470.20	15.78	0.0
MEAN	510.8	11.5	6.08	12.67	5.20	0.0	0.50	0.67	6.36	0.0	367.	357.	18.	0.	734.50	578.37	3.16	0.0
STD	335.18	7.43	2.57	4.13	2.39	0.0	0.0	0.27	3.90	0.0	236.	224.	12.	0.	471.09	418.36	2.48	0.0

STNT = Stationary Net (Gill and/or Trammel)
SHKR = Shocker

Table 16. (Continued)

MONTH = 10

STAT	NUMBER OF SPECIMENS	NUMBER OF SPP.	NUMBER OF SPP. FOR EACH GEAR TYPE				TIME FISHED FOR EACH GEAR TYPE				TOTAL NUMBER OF FISH				CATCH / EFFORT (FISH/HOUR)			
			TRAWL	SEINE	STNT	SHKR	TRAWL	SEINE	STNT	SHKR	TRAWL	SEINE	STNT	SHKR	TRAWL	SEINE	STNT	SHKR
1	92	11	5	0	8	0	0.12	0.0	6.00	0.0	56.	0.	36.	0.	460.00	0.0	6.00	0.0
2	581	16	5	14	0	0	0.50	0.58	0.0	0.0	322.	259.	0.	0.	644.00	444.00	0.0	0.0
3	291	5	5	0	0	0	0.42	0.0	0.0	0.0	291.	0.	0.	0.	698.00	0.0	0.0	0.0
4	1242	20	4	14	6	0	0.50	1.08	4.00	0.0	506.	696.	40.	0.	1012.00	642.50	10.00	0.0
5	113	8	8	0	0	0	0.50	0.0	0.0	0.0	113.	0.	0.	0.	226.00	0.0	0.0	0.0
6	420	28	6	20	6	0	0.50	0.67	5.00	0.0	156.	255.	9.	0.	312.00	382.50	1.80	0.0
7	491	7	7	0	0	0	0.50	0.0	0.0	0.0	491.	0.	0.	0.	982.00	0.0	0.0	0.0
8	483	9	1	8	1	0	0.50	0.58	4.50	0.0	188.	294.	1.	0.	376.00	504.00	0.22	0.0
9	928	7	7	0	0	0	0.50	0.0	0.0	0.0	928.	0.	0.	0.	1856.00	0.0	0.0	0.0
10	757	12	7	4	5	0	0.50	0.50	4.50	0.0	367.	376.	14.	0.	734.00	752.00	3.11	0.0
11	527	4	4	0	0	0	0.50	0.0	0.0	0.0	527.	0.	0.	0.	1054.00	0.0	0.0	0.0
12	202	4	4	0	0	0	0.50	0.0	0.0	0.0	202.	0.	0.	0.	404.00	0.0	0.0	0.0
17	149	14	0	14	0	0	0.0	0.67	0.0	0.0	0.	149.	0.	0.	0.0	223.50	0.0	0.0
SUM	6276.	145.	63.0	74.0	26.0	0.0	5.54	4.08	24.00	0.0	4147.	2029.	100.	0.	8778.00	2948.50	21.13	0.0
MEAN	482.8	11.2	5.25	12.33	5.20	0.0	0.46	0.68	4.80	0.0	346.	338.	20.	0.	731.50	491.42	4.23	0.0
STD	339.35	6.97	1.91	5.57	2.59	0.0	0.11	0.21	0.76	0.0	242.	190.	17.	0.	451.98	188.03	3.86	0.0

STNT = Stationary Net (Gill and/or Trammel)
SHKR = Shocker

Table 16. (Continued)

MONTH = 11

STAT	NUMBER OF SPECIMNS	NUMBER OF SPP.	NUMBER OF SPP. FOR EACH GEAR TYPE				TIME FISHED FOR EACH GEAR TYPE				TOTAL NUMBER OF FISH				CATCH / EFFORT (FISH/HOUR)			
			TRAWL	SEINE	STNT	SHKR	TRAWL	SEINE	STNT	SHKR	TRAWL	SEINE	STNT	SHKR	TRAWL	SEINE	STNT	SHKR
1	201	7	4	0	4	0	0.50	0.0	4.00	0.0	195.	0.	6.	0.	390.00	0.0	1.50	0.0
2	638	16	5	12	0	0	0.50	0.50	0.0	0.0	193.	445.	0.	0.	386.00	850.00	0.0	0.0
3	460	2	2	0	0	0	0.50	0.0	0.0	0.0	460.	0.	0.	0.	920.00	0.0	0.0	0.0
4	911	20	7	11	3	0	1.00	0.75	5.00	0.0	458.	447.	6.	0.	458.00	596.00	1.20	0.0
5	369	6	6	0	0	0	0.50	0.0	0.0	0.0	369.	0.	0.	0.	738.00	0.0	0.0	0.0
6	708	31	3	24	8	0	0.50	0.50	5.50	0.0	125.	540.	43.	0.	250.00	1080.00	7.82	0.0
7	70	8	8	0	0	0	0.50	0.0	0.0	0.0	70.	0.	0.	0.	140.00	0.0	0.0	0.0
8	168	17	1	14	4	0	0.50	0.83	4.00	0.0	30.	130.	8.	0.	60.00	156.00	2.00	0.0
9	65	4	4	0	0	0	0.50	0.0	0.0	0.0	65.	0.	0.	0.	130.00	0.0	0.0	0.0
10	1005	12	4	5	5	0	0.50	0.33	5.33	0.0	815.	140.	50.	0.	1630.00	420.00	5.38	0.0
11	923	2	2	0	0	0	0.50	0.0	0.0	0.0	923.	0.	0.	0.	1846.00	0.0	0.0	0.0
12	541	4	4	0	0	0	0.50	0.0	0.0	0.0	541.	0.	0.	0.	1082.00	0.0	0.0	0.0
17	93	15	0	11	0	7	0.0	0.75	0.0	0.75	0.	77.	0.	16.	0.0	102.70	0.0	21.33
SUM	6152.	144.	50.0	77.0	24.0	7.0	6.50	3.66	23.83	0.75	4244.	1779.	113.	16.	8030.00	3244.70	21.90	21.33
MEAN	473.2	11.1	4.17	12.83	4.80	7.00	0.54	0.61	4.77	0.75	354.	297.	23.	16.	669.17	540.78	4.38	21.33
STD	343.48	8.51	2.08	6.24	1.92	0.0	0.14	0.20	0.72	0.0	296.	202.	22.	0.	592.87	392.51	3.90	0.0

STNT = Stationary Net (Gill and/or Trammel)
SHKR = Shocker

Table 16. (Continued)

MONTH = 12

STAT	NUMBER OF SPECIMENS	NUMBER OF SPP.	NUMBER OF SPP. FOR EACH GEAR TYPE				TIME FISHED FOR EACH GEAR TYPE				TOTAL NUMBER OF FISH				CATCH / EFFORT (FISH/HOUR)			
			TRAWL	SEINE	STNT	SHKR	TRAWL	SEINE	STNT	SHKR	TRAWL	SEINE	STNT	SHKR	TRAWL	SEINE	STNT	SHKR
1	62	9	8	0	3	0	0.50	0.0	4.67	0.0	56.	0.	6.	0.	112.00	0.0	1.29	0.0
2	1028	18	8	11	0	0	0.50	0.50	0.0	0.0	130.	898.	0.	0.	260.00	1796.00	0.0	0.0
3	8	2	2	0	0	0	0.50	0.0	0.0	0.0	8.	0.	0.	0.	16.00	0.0	0.0	0.0
4	39	3	2	2	0	0	0.50	0.50	4.00	0.0	6.	33.	0.	0.	12.00	66.00	0.0	0.0
5	247	6	6	0	0	0	0.50	0.0	0.0	0.0	247.	0.	0.	0.	494.00	0.0	0.0	0.0
6	141	11	4	6	2	0	0.50	0.50	5.00	0.0	64.	53.	24.	0.	128.00	106.00	4.80	0.0
7	42	2	2	0	0	0	0.50	0.0	0.0	0.0	42.	0.	0.	0.	84.00	0.0	0.0	0.0
8	283	18	6	10	5	0	0.50	0.50	4.25	0.0	72.	153.	58.	0.	144.00	306.00	13.65	0.0
9	514	9	9	0	0	0	0.50	0.0	0.0	0.0	514.	0.	0.	0.	1028.00	0.0	0.0	0.0
10	475	17	5	13	4	0	0.50	0.42	4.00	0.0	45.	425.	5.	0.	90.00	1020.00	1.25	0.0
11	246	6	6	0	0	0	0.50	0.0	0.0	0.0	246.	0.	0.	0.	492.00	0.0	0.0	0.0
12	53	2	2	0	0	0	0.50	0.0	0.0	0.0	53.	0.	0.	0.	106.00	0.0	0.0	0.0
17	161	10	0	10	0	0	0.0	0.50	0.0	0.0	0.	161.	0.	0.	0.0	322.00	0.0	0.0
SUM	3299.	113.	60.0	52.0	14.0	0.0	6.00	2.92	21.92	0.0	1483.	1723.	93.	0.	2966.00	3616.00	20.99	0.0
MEAN	253.8	8.7	5.00	8.67	3.50	0.0	0.50	0.49	4.38	0.0	124.	287.	23.	0.	247.17	602.67	5.25	0.0
STD	283.85	5.99	2.59	3.98	1.29	0.0	0.0	0.03	0.44	0.0	147.	330.	25.	0.	294.47	678.19	5.84	0.0

STNT = Stationary Net (Gill and/or Trammel)
SHKR = Shocker

Table 17. Monthly Catch Results for Lake Pontchartrain, LA, 1978

MONTH = 1

STAT	NUMBER OF SPECIMENS	NUMBER OF SPP.	NUMBER OF SPP. FOR EACH GEAR TYPE				TIME FISHED FOR EACH GEAR TYPE				TOTAL NUMBER OF FISH				CATCH / EFFORT (FISH/HOUR)			
			TRAWL	SEINE	STNT	SHKR	TRAWL	SEINE	STNT	SHKR	TRAWL	SEINE	STNT	SHKR	TRAWL	SEINE	STNT	SHKR
13	2180	13	8	12	0	0	0.17	0.75	0.0	0.0	258.	1922.	0.	0.	1548.00	2562.70	0.0	0.0
14	146	13	9	6	0	0	0.25	0.33	0.0	0.0	77.	69.	0.	0.	308.00	207.00	0.0	0.0
15	84	8	8	0	0	0	0.50	0.0	0.0	0.0	84.	0.	0.	0.	168.00	0.0	0.0	0.0
16	89	8	0	8	0	0	0.0	0.75	0.0	0.0	0.	89.	0.	0.	0.0	118.70	0.0	0.0
SUM	2499.	42.	25.0	26.0	0.0	0.0	0.92	1.83	0.0	0.0	419.	2080.	0.	0.	2024.00	2888.40	0.0	0.0
MEAN	624.7	10.5	8.33	8.67	0.0	0.0	0.31	0.61	0.0	0.0	140.	693.	0.	0.	674.67	962.80	0.0	0.0
STD	1037.21	2.89	0.58	3.06	0.0	0.0	0.17	0.24	0.0	0.0	103.	1064.	0.	0.	759.56	1386.26	0.0	0.0

MONTH = 2

STAT	NUMBER OF SPECIMENS	NUMBER OF SPP.	NUMBER OF SPP. FOR EACH GEAR TYPE				TIME FISHED FOR EACH GEAR TYPE				TOTAL NUMBER OF FISH				CATCH / EFFORT (FISH/HOUR)			
			TRAWL	SEINE	STNT	SHKR	TRAWL	SEINE	STNT	SHKR	TRAWL	SEINE	STNT	SHKR	TRAWL	SEINE	STNT	SHKR
13	453	18	14	8	0	0	0.42	0.25	0.0	0.0	300.	153.	0.	0.	720.00	612.00	0.0	0.0
14	1153	17	12	9	0	0	0.33	0.58	0.0	0.0	239.	914.	0.	0.	717.00	1566.90	0.0	0.0
15	250	11	7	5	0	0	0.33	0.50	0.0	0.0	29.	221.	0.	0.	87.00	442.00	0.0	0.0
16	115	13	8	7	0	0	0.25	0.42	0.0	0.0	47.	68.	0.	0.	188.00	163.20	0.0	0.0
SUM	1971.	59.	41.0	29.0	0.0	0.0	1.33	1.75	0.0	0.0	615.	1356.	0.	0.	1712.00	2784.10	0.0	0.0
MEAN	492.7	14.8	10.25	7.25	0.0	0.0	0.33	0.44	0.0	0.0	154.	339.	0.	0.	428.00	696.02	0.0	0.0
STD	461.57	3.30	3.30	1.71	0.0	0.0	0.07	0.14	0.0	0.0	136.	388.	0.	0.	337.97	609.35	0.0	0.0

STNT = Stationary Net (Gill and/or Trammel)
SHKR = Shocker

Table 17. (Continued)

MONTH = 3

STAT	NUMBER OF SPECIMENS	NUMBER OF SPP.	NUMBER OF SPP. FOR EACH GEAR TYPE				TIME FISHED FOR EACH GEAR TYPE				TOTAL NUMBER OF FISH				CATCH / EFFORT (FISH/HOUR)			
			TRAWL	SEINE	STNT	SHKR	TRAWL	SEINE	STNT	SHKR	TRAWL	SEINE	STNT	SHKR	TRAWL	SEINE	STNT	SHKR
13	588	15	8	8	0	0	0.42	0.33	0.0	0.0	205.	383.	0.	0.	492.00	1149.00	0.0	0.0
14	573	17	7	11	5	0	0.25	0.42	4.50	0.0	186.	369.	18.	0.	744.00	885.60	4.00	0.0
15	216	10	3	7	0	0	0.25	1.00	0.0	0.0	9.	207.	0.	0.	36.00	207.00	0.0	0.0
16	150	13	4	10	0	0	0.12	0.75	0.0	0.0	11.	139.	0.	0.	94.00	185.30	0.0	0.0
SUM	1527.	55.	22.0	36.0	5.0	0.0	1.04	2.50	4.50	0.0	411.	1098.	18.	0.	1366.00	2426.90	4.00	0.0
MEAN	381.7	13.8	5.50	9.00	5.00	0.0	0.26	0.63	4.50	0.0	103.	275.	18.	0.	341.50	606.72	4.00	0.0
STD	231.15	2.99	2.38	1.83	0.0	0.0	0.12	0.31	0.0	0.0	107.	121.	0.	0.	336.28	486.21	0.0	0.0

MONTH = 4

STAT	NUMBER OF SPECIMENS	NUMBER OF SPP.	NUMBER OF SPP. FOR EACH GEAR TYPE				TIME FISHED FOR EACH GEAR TYPE				TOTAL NUMBER OF FISH				CATCH / EFFORT (FISH/HOUR)			
			TRAWL	SEINE	STNT	SHKR	TRAWL	SEINE	STNT	SHKR	TRAWL	SEINE	STNT	SHKR	TRAWL	SEINE	STNT	SHKR
13	292	10	0	10	0	0	0.0	0.0	0.0	0.0	0.	0.	0.	0.	0.0	0.0	0.0	0.0
14	1221	13	4	13	0	0	0.25	0.58	0.0	0.0	167.	1054.	0.	0.	668.00	1806.90	0.0	0.0
15	162	12	8	4	0	0	0.33	1.00	0.0	0.0	25.	137.	0.	0.	75.00	137.00	0.0	0.0
16	104	12	3	9	0	0	0.13	0.33	0.0	0.0	7.	97.	0.	0.	53.00	291.00	0.0	0.0
SUM	1779.	47.	15.0	36.0	0.0	0.0	0.71	1.91	0.0	0.0	199.	1288.	0.	0.	796.00	2234.90	0.0	0.0
MEAN	444.7	11.8	5.00	9.00	0.0	0.0	0.24	0.64	0.0	0.0	66.	429.	0.	0.	265.33	744.97	0.0	0.0
STD	523.44	1.26	2.65	3.74	0.0	0.0	0.10	0.34	0.0	0.0	88.	541.	0.	0.	348.89	922.88	0.0	0.0

STNT = Stationary Net (Gill and/or Trammel)
SHKR = Shocker

Table 17. (Continued)

MONTH = 5

STAT	NUMBER OF SPECIMENS	NUMBER OF SPP.	NUMBER OF SPP. FOR EACH GEAR TYPE				TIME FISHED FOR EACH GEAR TYPE				TOTAL NUMBER OF FISH				CATCH / EFFORT (FISH/HOUR)			
			TRAWL	SEINE	STNT	SHKR	TRAWL	SEINE	STNT	SHKR	TRAWL	SEINE	STNT	SHKR	TRAWL	SEINE	STNT	SHKR
13	913	5	0	5	0	0	0.0	0.50	0.0	0.0	0.	913.	0.	0.	0.0	1826.00	0.0	0.0
14	1414	13	6	7	0	0	0.25	0.33	3.67	0.0	129.	1285.	0.	0.	516.00	3855.00	0.0	0.0
15	161	9	5	5	0	0	0.50	0.67	0.0	0.0	30.	131.	0.	0.	60.00	196.50	0.0	0.0
16	25	10	2	9	0	0	0.17	0.50	0.0	0.0	2.	23.	0.	0.	12.00	46.00	0.0	0.0
SUM	2513.	37.	13.0	26.0	0.0	0.0	0.92	2.00	3.67	0.0	161.	2352.	0.	0.	588.00	5923.50	0.0	0.0
MEAN	628.2	9.3	4.33	6.50	0.0	0.0	0.31	0.50	3.67	0.0	54.	588.	0.	0.	196.00	1480.87	0.0	0.0
STD	653.38	3.30	2.08	1.91	0.0	0.0	0.17	0.14	0.0	0.0	67.	611.	0.	0.	278.17	1776.14	0.0	0.0

MONTH = 6

STAT	NUMBER OF SPECIMENS	NUMBER OF SPP.	NUMBER OF SPP. FOR EACH GEAR TYPE				TIME FISHED FOR EACH GEAR TYPE				TOTAL NUMBER OF FISH				CATCH / EFFORT (FISH/HOUR)			
			TRAWL	SEINE	STNT	SHKR	TRAWL	SEINE	STNT	SHKR	TRAWL	SEINE	STNT	SHKR	TRAWL	SEINE	STNT	SHKR
13	98	10	1	9	0	0	0.17	0.33	0.0	0.0	2.	96.	0.	0.	12.00	288.00	0.0	0.0
14	290	15	6	14	0	0	0.25	0.67	0.0	0.0	100.	190.	0.	0.	400.00	285.00	0.0	0.0
	49	9	3	6	0	0	0.25	0.50	0.0	0.0	4.	45.	0.	0.	16.00	90.00	0.0	0.0
[illegible]	207	13	3	10	0	0	0.17	0.50	0.0	0.0	62.	145.	0.	0.	372.00	290.00	0.0	0.0
SUM	644.	51.	13.0	39.0	0.0	0.0	0.84	2.00	0.0	0.0	168.	476.	0.	0.	800.00	953.00	0.0	0.0
MEAN	161.0	12.8	3.25	9.75	0.0	0.0	0.21	0.50	0.0	0.0	42.	119.	0.	0.	200.00	238.25	0.0	0.0
STD	108.43	4.50	2.06	3.30	0.0	0.0	0.05	0.14	0.0	0.0	48.	63.	0.	0.	215.08	98.85	0.0	0.0

STNT = Stationary Net (Gill and/or Trammel)
SHKR = Shocker

Table 17. (Continued)

MONTH = 7

STAT	NUMBER OF SPECIMENS	NUMBER OF SPP.	NUMBER OF SPP. FOR EACH GEAR TYPE: TRAWL	SEINE	STNT	SHKR	TIME FISHED FOR EACH GEAR TYPE: TRAWL	SEINE	STNT	SHKR	TOTAL NUMBER OF FISH: TRAWL	SEINE	STNT	SHKR	CATCH / EFFORT (FISH/HOUR): TRAWL	SEINE	STNT	SHKR
13	111	13	12	3	0	0	0.12	0.17	0.0	0.0	102.	9.	0.	0.	874.00	54.00	0.0	0.0
14	832	18	8	12	0	0	0.25	0.42	0.0	0.0	308.	524.	0.	0.	1232.00	1257.60	0.0	0.0
15	137	9	0	3	0	8	0.0	0.50	0.0	4.00	0.	94.	0.	43.	0.0	188.00	0.0	10.75
16	281	19	0	8	0	16	0.0	0.50	0.0	1.00	0.	143.	0.	138.	0.0	286.00	0.0	138.00
SUM	1361.	59.	20.0	26.0	0.0	24.0	0.37	1.59	0.0	5.00	410.	770.	0.	181.	2106.00	1785.60	0.0	148.75
MEAN	340.2	14.8	10.00	6.50	0.0	12.00	0.19	0.40	0.0	2.50	205.	193.	0.	91.	1053.00	446.40	0.0	74.38
STD	336.25	4.65	2.83	4.36	0.0	5.66	0.09	0.16	0.0	2.12	146.	228.	0.	67.	253.14	549.10	0.0	89.98

MONTH = 8

STAT	NUMBER OF SPECIMENS	NUMBER OF SPP.	NUMBER OF SPP. FOR EACH GEAR TYPE: TRAWL	SEINE	STNT	SHKR	TIME FISHED FOR EACH GEAR TYPE: TRAWL	SEINE	STNT	SHKR	TOTAL NUMBER OF FISH: TRAWL	SEINE	STNT	SHKR	CATCH / EFFORT (FISH/HOUR): TRAWL	SEINE	STNT	SHKR
13	34	9	0	9	0	0	0.0	0.25	0.0	0.0	0.	34.	0.	0.	0.0	136.00	0.0	0.0
14	1356	20	10	12	0	0	0.25	0.50	0.0	0.0	325.	1031.	0.	0.	1300.00	2062.00	0.0	0.0
15	187	12	6	6	0	0	0.33	0.83	0.0	0.0	20.	167.	0.	0.	60.00	200.40	0.0	0.0
16	161	7	0	7	0	0	0.0	0.58	0.0	0.0	0.	161.	0.	0.	0.0	276.00	0.0	0.0
SUM	1738.	48.	16.0	34.0	0.0	0.0	0.58	2.16	0.0	0.0	345.	1393.	0.	0.	1360.00	2674.40	0.0	0.0
MEAN	434.5	12.0	8.00	8.50	0.0	0.0	0.29	0.54	0.0	0.0	173.	348.	0.	0.	680.00	668.60	0.0	0.0
STD	617.96	5.72	2.83	2.65	0.0	0.0	0.06	0.24	0.0	0.0	216.	459.	0.	0.	876.81	930.69	0.0	0.0

STNT = Stationary Net (Gill and/or Trammel)
SHKR = Shocker

Table 17. (Continued)

MONTH = 9

STAT	NUMBER OF SPECIMENS	NUMBER OF SPP.	NUMBER OF SPP. FOR EACH GEAR TYPE				TIME FISHED FOR EACH GEAR TYPE				TOTAL NUMBER OF FISH				CATCH / EFFORT (FISH/HOUR)			
			TRAWL	SEINE	STNT	SHKR	TRAWL	SEINE	STNT	SHKR	TRAWL	SEINE	STNT	SHKR	TRAWL	SEINE	STNT	SHKR
13	198	12	0	12	0	0	0.0	0.50	0.0	0.0	0.	198.	0.	0.	0.0	396.00	0.0	0.0
14	1165	20	8	13	0	0	0.25	0.58	0.0	0.0	786.	379.	0.	0.	3144.00	649.70	0.0	0.0
15	47	10	5	5	0	0	0.25	0.42	0.0	0.0	25.	22.	0.	0.	100.00	52.80	0.0	0.0
16	0	0	0	0	0	0	0.0	0.0	0.0	0.0	0.	0.	0.	0.	0.0	0.0	0.0	0.0
SUM	1410.	42.	13.0	30.0	0.0	0.0	0.50	1.50	0.0	0.0	811.	599.	0.	0.	3244.00	1098.50	0.0	0.0
MEAN	470.0	14.0	6.50	10.00	0.0	0.0	0.25	0.50	0.0	0.0	406.	200.	0.	0.	1622.00	366.17	0.0	0.0
STD	606.60	5.29	2.12	4.36	0.0	0.0	0.0	0.08	0.0	0.0	538.	179.	0.	0.	2152.43	299.57	0.0	0.0

MONTH = 10

STAT	NUMBER OF SPECIMENS	NUMBER OF SPP.	NUMBER OF SPP. FOR EACH GEAR TYPE				TIME FISHED FOR EACH GEAR TYPE				TOTAL NUMBER OF FISH				CATCH / EFFORT (FISH/HOUR)			
			TRAWL	SEINE	STNT	SHKR	TRAWL	SEINE	STNT	SHKR	TRAWL	SEINE	STNT	SHKR	TRAWL	SEINE	STNT	SHKR
13	343	18	16	4	0	0	0.22	0.42	0.0	0.0	217.	126.	0.	0.	1002.00	302.40	0.0	0.0
14	336	15	9	8	0	0	0.25	0.50	0.0	0.0	210.	126.	0.	0.	840.00	252.00	0.0	0.0
15	192	12	0	0	0	12	0.0	0.0	0.0	2.50	0.	0.	0.	192.	0.0	0.0	0.0	76.80
16	317	13	0	13	0	0	0.0	0.58	0.0	0.0	0.	317.	0.	0.	0.0	543.40	0.0	0.0
SUM	1188.	58.	25.0	25.0	0.0	12.0	0.47	1.50	0.0	2.50	427.	569.	0.	192.	1842.00	1097.80	0.0	76.80
MEAN	297.0	14.5	12.50	8.33	0.0	12.00	0.24	0.50	0.0	2.50	214.	190.	0.	192.	921.00	365.93	0.0	76.80
STD	70.86	2.65	4.95	4.51	0.0	0.0	0.02	0.08	0.0	0.0	5.	110.	0.	0.	114.55	155.74	0.0	0.0

STNT = Stationary Net (Gill and/or Trammel)
SHKR = Shocker

Table 17. (Continued)

MONTH = 11

STAT	NUMBER OF SPECIMNS	NUMBER OF SPP.	NUMBER OF SPP. FOR EACH GEAR TYPE				TIME FISHED FOR EACH GEAR TYPE				TOTAL NUMBER OF FISH				CATCH / EFFORT (FISH/HOUR)			
			TRAWL	SEINE	STNT	SHKR	TRAWL	SEINE	STNT	SHKR	TRAWL	SEINE	STNT	SHKR	TRAWL	SEINE	STNT	SHKR
13	175	10	10	0	0	0	0.10	0.0	0.0	0.0	175.	0.	0.	0.	1750.0C	0.0	C.0	0.0
14	1019	24	7	10	0	14	0.25	0.5C	0.0	1.25	546.	407.	0.	66.	2184.00	814.00	0.0	52.80
15	163	14	0	0	0	14	0.0	0.0	0.0	1.50	0.	0.	0.	163.	0.0	0.0	0.0	108.67
16	455	20	7	13	0	0	0.25	0.5C	0.0	0.0	275.	180.	0.	0.	1100.00	360.00	0.0	0.0
SUM	1812.	68.	24.0	23.0	0.0	28.0	0.60	1.00	0.0	2.75	996.	587.	0.	229.	5034.0C	1174.00	0.0	161.47
MEAN	453.0	17.0	8.00	11.50	0.0	14.00	0.20	0.5C	0.0	1.38	332.	294.	0.	115.	1678.0C	587.CC	0.0	80.74
STD	400.73	6.22	1.73	2.12	0.0	0.0	0.09	0.0	0.0	0.18	192.	161.	0.	69.	545.58	321.03	C.0	39.51

MONTH = 12

STAT	NUMBER OF SPECIMNS	NUMBER OF SPP.	NUMBER OF SPP. FOR EACH GEAR TYPE				TIME FISHED FOR EACH GEAR TYPE				TOTAL NUMBER OF FISH				CATCH / EFFORT (FISH/HOUR)			
			TRAWL	SEINE	STNT	SHKR	TRAWL	SEINE	STNT	SHKR	TRAWL	SEINE	STNT	SHKR	TRAWL	SEINE	STNT	SHKR
13	354	13	C	13	0	0	0.0	0.25	0.0	0.0	0.	354.	0.	0.	0.0	1416.0C	C.0	0.0
14	775	17	14	7	0	0	0.25	0.50	0.0	0.0	208.	567.	0.	0.	832.C0	1134.0C	0.0	0.0
15	398	18	0	5	0	13	0.0	0.33	0.0	1.00	0.	309.	0.	89.	0.0	927.00	0.0	89.0C
16	228	10	6	6	0	0	0.13	0.33	0.0	0.0	168.	60.	0.	0.	1260.00	180.0C	0.0	0.0
SUM	1755.	58.	20.0	31.0	0.0	13.0	0.38	1.41	0.0	1.00	376.	1290.	0.	89.	2092.00	3657.C0	0.0	89.0C
MEAN	438.7	14.5	10.00	7.75	0.0	13.00	0.19	0.35	0.0	1.00	188.	323.	0.	89.	1046.00	914.25	0.0	89.0C
STD	235.46	3.70	5.66	3.59	0.0	0.0	0.08	0.11	0.0	0.0	28.	208.	0.	0.	302.64	528.94	C.0	0.0

STNT = Stationary Net (Gill and/or Trammel)
SHKR = Shocker

Table 18. Population Density Estimates $\left(\frac{\text{fish} \times 10^3}{m^2}\right)$ Trawled in Lake Pontchartrain, Stations 1-12, 197[illegible]
(Based on Average of 11,263 m^2 Swept)

Month	Stations 1	2	3	4	5	6	7	8	9	10	11	12	Month $\bar{X}$	Mdn	S	S^2	CV
JAN	2	2	.4	5	3	5	5	5	2	1	M	1	2.9	2.5	1.8	3.4	62.1
FEB	2	7	3	7	14	1	4	14	2	5	2	14	6.3	4.5	5.0	25.5	79.4
MAR	5	11	.4	7	11	21	3	7	4	17	17	M	9.4	7.0	6.6	43.7	70.2
APR	4	12	22	16	2	16	9	5	7	7	5	8	9.4	7.5	5.9	35.4	62.8
MAY	14	10	2	62	16	12	9	7	1	18	3	1	12.9	9.5	16.5	273.4	127.9
JUN	21	27	25	12	5	7	8	4	6	12	0	16	11.9	10.0	8.7	75.0	73.1
JUL	3	7	65	34	40	50	21	19	40	65	60	31	36.3	37.0	21.2	450.8	58.4
AUG	3	17	30	31	19	14	10	21	57	63	12	19	25.5	19.0	17.4	303.4	68.2
SEP	4	28	15	40	22	35	20	19	93	23	40	23	32.7	23.0	20.8	430.6	63.6
OCT	21	29	31	45	10	14	44	17	82	33	47	18	32.2	30.0	20.0	399.5	62.1
NOV	17	17	41	20	33	11	6	3	6	72	82	48	29.7	16.5	26.3	691.0	86.6
DEC	5	12	.7	.5	22	6	4	6	46	4	22	5	11.1	5.5	13.2	173.1	118.9
YEAR $\bar{X}$	11.8	14.9	19.6	23.3	16.4	16.0	11.9	10.6	28.8	26.7	26.4	16.7					
Mdn	5.0	12.0	18.5	18.0	16.5	13.0	8.5	7.0	6.5	17.5	17.0	16.0					
S	10.1	8.9	20.2	19.1	11.7	13.9	11.7	6.8	33.7	25.8	27.3	13.9					
S^2	101.7	77.4	408.5	363.6	135.9	192.5	136.4	46.6	1137.0	664.6	744.3	194.4					
CV	85.6	59.7	103.1	82.0	71.3	86.9	98.3	64.2	117.0	96.6	103.4	83.2					

*Corrections made for trawls of less than 0.5 hr.

M = station missing.

Table 19. **Biomass (gm/m^2) of Demersal Fish Collected by Trawl in Lake Pontchartrain, 1978 (Wet Weight of Preserved Fish)**

	Station															
	1	2	3	4	5	6	7	8	9	10	11	12	STA $\bar{X}$	Mdn	S	S^2
JAN	.025	1.642	T	.111	.515	.043	.007	.062	.050	.040	M	.020	.229	.043	.491	.241
FEB	.088	.171	.275	.097	.070	.003	.003	.043	.109	.044	.070	.055	.086	.070	.075	.006
MAR	.003	.013	T	.043	.029	.035	.007	.018	.891	.051	.075	M	.106	.029	.261	.068
APR	.012	.027	.051	.094	.005	.055	.078	.008	.007	.006	.124	.058	.044	.039	.040	.002
MAY	.088	.041	.061	.081	.104	.083	.229	.077	.826	.022	.131	.002	.145	.082	.222	.049
JUN	.033	.028	.009	.063	.003	.019	.253	.231	.038	.013	0	.012	.059	.024	.088	.008
JUL	.017	.022	.812	.321	.344	.534	.223	.200	.299	.591	.887	.180	.369	.310	.283	.080
AUG	.025	.065	.613	.060	.352	.122	.229	.062	.456	.775	.230	.020	.209	.176	.189	.036
SEP	.107	.092	.010	.910	.621	.456	.756	.349	.996	.323	.638	.048	.442	.403	.343	.118
OCT	.660	.225	.099	.102	.918	.091	1.975	.012	.370	.265	.317	.129	.430	.245	.552	.306
NOV	.025	.057	.017	.377	1.909	.070	.610	M	.125	.125	.167	.158	.331	.125	.552	.305
DEC	2.303	3.331	.102	T	.614	.167	.005	.030	1.276	.053	1.285	.014	.765	.135	1.090	1.189
Year $\bar{X}$	.282	.476	.171	.188	.457	.140	.365	.099	.454	.151	.357	.063	---	---	---	---
Mdn	.029	.061	.056	.096	.348	.077	.226	.062	.335	.052	.167	.048	---	---	---	---
S	.662	1.008	.268	.253	.545	.173	.562	.111	.436	.179	.409	.063	---	---	---	---
S^2	.438	1.016	.072	.064	.297	.030	.316	.012	.190	.032	.167	.004	---	---	---	---
Rank	6/12	1/8	8/9	7/5	2/1	10/6	4/3	11/7	3/2	9/10	5/4	12/11	---	---	---	---

T: (Trace) less than .001 gm/m^2.
M: Missing data.
Rank: Stations ranked by mean and median.

Table 20. Salinity Ranges for the 20 Most Abundant Fish Species in Lake Pontchartrain, LA, 1978

	January-June					July-December					Year				
	Min.	Max.	Mean	SD*	No. Coll.	Min.	Max.	Mean	SD*	No. Coll.	Min.	Max.	Mean	SD*	No. Coll.
Anchoa mitchilli	0.0	5.2	1.87	1.56	93	0.0	8.7	2.94	1.61	131	0.0	8.7	2.49	1.58	224
Micropogonias undulatus	0.0	5.2	1.79	1.69	100	0.0	8.7	3.02	1.57	102	0.0	8.7	2.42	1.63	202
Brevoortia patronus	0.0	5.2	1.78	1.64	90	0.5	8.5	2.96	1.31	57	0.0	8.5	2.24	1.52	147
Menidia beryllina	0.0	5.0	1.56	1.91	56	0.0	8.5	2.94	1.74	64	0.0	8.5	2.30	1.81	120
Cyprinodon variegatus	0.0	5.0	1.41	1.50	40	0.0	6.0	2.15	1.62	29	0.0	6.0	1.72	1.54	69
Lucania parva	0.0	5.0	1.38	1.92	39	0.0	6.7	2.79	1.58	45	0.0	6.7	2.14	1.73	84
Poecilia latipinna	0.0	4.2	1.10	1.90	17	0.0	8.5	2.66	2.32	20	0.0	8.5	1.94	2.10	37
Syngnathus scovelli	0.4	3.2	1.98	1.65	11	0.0	8.5	3.32	1.77	44	0.0	8.5	3.06	1.73	55
Leiostomus xanthurus	0.1	5.0	2.20	1.56	47	0.2	8.5	3.36	1.66	82	0.1	8.5	2.94	[illegible]	129
Gambusia affinis	0.0	4.2	0.99	1.21	29	0.0	4.4	1.60	1.41	17	0.0	4.4	1.22	1.27	46
Fundulus grandis	0.0	5.0	1.82	1.25	34	0.0	5.0	2.03	1.23	21	0.0	5.0	1.90	[illegible]	55
Arius felis	0.9	5.2	2.55	1.12	25	0.7	8.7	3.13	1.56	72	0.7	8.7	2.98	[illegible]	97
Mugil cephalus	0.0	5.0	1.78	2.12	55	0.8	8.5	3.49	1.79	29	0.0	8.5	2.37	[illegible]	84
Lepomis punctatus	0.0	3.2	1.15	1.96	17	0.3	6.7	2.67	1.62	34	0.0	6.7	2.17	1.72	51
Lepomis macrochirus	0.0	3.2	0.61	1.73	16	0.2	5.0	2.06	1.41	32	0.0	5.0	1.58	1.51	48
Cynoscion arenarius	0.5	5.2	2.98	1.82	10	0.5	8.5	3.48	1.49	48	0.5	8.5	3.39	1.53	58
Ictalurus furcatus	0.0	3.1	1.16	1.09	43	0.3	3.0	1.85	0.83	23	0.0	3.1	1.40	[illegible]	66
Lepomis microlophus	0.0	5.0	1.37	2.00	17	0.4	5.6	2.60	1.45	27	0.0	5.6	2.13	[illegible]	[illegible]
Heterandria formosa	0.0	3.2	0.83	0.89	15	0.0	2.3	1.02	0.85	11	0.0	3.2	0.91	0.85	26
Gobiosoma bosci	0.2	3.2	1.65	1.85	10	0.0	8.5	3.10	1.78	31	0.0	8.5	2.74	1.78	41

*SD = Standard Deviation

Table 21. Provisional Classification of Lake Pontchartrain, LA, Fishes Based on Apparent Salinity Tolerance*

I. Freshwater Species

A. Strictly Freshwater. (10 species)

Amia calva	*Pylodictis olivaris*
Cyprinus carpio	*Labidesthes sicculus*
Notemigonus crysoleucas	*Centrarchus macropterus*
Carpiodes carpio	*Lepomis megalotis*
Ictalurus natalis	*Aplodinotus grunniens*

B. Facultative Invaders of Brackish Water.

1. Sporadic Invasion by Stragglers into Water of Low Salinity. (7 species)

Polyodon spathula	*Morone chrysops*
Ictalurus punctatus	*Morone mississippiensis*
Fundulus chrysotus	*Lepomis macrochirus*
Heterandria formosa	

2. Frequent Invasion, Probably for a Considerable Time, into Water of Low Salinity (at Least 4.5°/₀₀); Maximum Tolerance Presumably Greater than B-1. (13 species)

Lepisosteus oculatus	*Chaenobryttus gulosus*
Lepisosteus osseus	*Lepomis microlophus*
Lepisosteus spatula	*Lepomis punctatus*
Ictalurus furcatus	*Micropterus salmoides*
Fundulus pulvereus	*Pomoxis nigromaculatus*
Gambusia affinis	*Gobionellus shufeldti*
Poecilia latipinna	

II. Euryhaline Species

A. *Anadromous Fishes* Entering Freshwater to Breed; Some are at Time Residual in Fresh Water. Commonly Entering Water of High Salinity. (5 species)

Acipenser oxyrhynchus	*Dorosoma petenense*
Alosa chrysochloris	*Strongylura marina* (at least a portion of the population)
Dorosoma cepedianum	

B. Catadromous Fishes Entering The Sea to Breed. (1 species)

Anguilla rostrata

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*Adapted from Bailey et al. 1954 and Darnell 1962b.

Table 21. (Continued)

C. Marine or Brackish-Water Fishes That Invade Strictly Fresh Water.

1. Frequent Invasion, Often for a Considerable Time and Distance; Some Species Occasionally Residual in Fresh Water. (12 species)

Carcharhinus leucas	Mugil cephalus
Anchoa mitchilli	Dormitator maculatus
Cyprinodon variegatus	Gobiosoma bosci
Lucania parva	Microgobius gulosus
Menidia beryllina	Paralichthys lethostigma
Syngnathus scovelli	Trinectes maculatus

2. Sporadic Invasion, Probably for a Brief Period and Usually for a Short Distance. Most Often Not Exceeding Tidal Water. (8 species)

Dasyatis sabina	Fundulus jenkinsi
Gobiesox strumosus	Fundulus similis
Adinia xenica	Membras martinica
Fundulus grandis	Gobionellus boleosoma

D. Marine Species. Facultative Invaders of Water of Moderate to Low Salinity. Not Entering Fresh Water (Probable Temporary Stragglers, Especially Young Fish, Excluded). (29 species)

Rhinoptera bonasus	Menticirrhus americanus
Elops saurus	Micropogonias undulatus
Brevoortia patronus	Pogonias cromis
Anchoa hepsetus	Sciaenops ocellata
Arius felis	Chaetodipterus faber
Bagre marinus	Polydactylus octonemus
Syngnathus louisianae	Astroscopus y-graecum
Caranx hippos	Chasmodes bosquianus
Oligoplites saurus	Microgobius thalassinus
Archosargus probatocephalus	Prionotus tribulus
Lagodon rhomboides	Citharichthys spilopterus
Bairdiella chrysura	Symphurus plagiusa
Cynoscion arenarius	Monacanthus hispidus
Cynoscion nebulosus	Sphoeroides parvus
Leiostomus xanthurus	

Table 22. Temperature Ranges for the 20 Most Abundant Fish Species in Lake Pontchartrain, LA, estuary, 1978

	January-June					July-December					Year				
	Min.	Max.	Mean	SD*	No. Coll.	Min.	Max.	Mean	SD*	No. Coll.	Min.	Max.	Mean	SD*	No. Coll.
Anchoa mitchilli	5.0	33.8	18.9	9.9	93	10.0	32.0	24.3	6.2	131	5.0	33.8	22.1	7.9	224
Micropogonias undulatus	5.0	31.0	17.9	10.2	100	10.5	32.0	24.3	6.3	102	5.0	32.0	21.1	8.4	202
Brevoortia patronus	5.0	31.0	18.6	9.5	90	10.5	32.0	24.7	6.2	57	5.0	32.0	21.0	8.4	147
Menidia beryllina	5.0	33.8	17.6	11.1	56	8.2	32.0	24.1	6.6	64	5.0	33.8	21.0	8.9	120
Cyprinodon variegatus	5.0	33.8	16.9	10.9	40	8.2	32.0	23.2	7.6	29	5.0	33.8	19.5	9.6	69
Lucania parva	5.0	33.8	17.0	11.5	39	10.5	32.0	24.1	6.3	45	5.0	33.8	20.8	9.1	84
Poecilia latipinna	7.0	33.8	21.1	8.8	17	10.8	32.0	22.7	7.2	20	7.0	33.8	21.9	7.8	37
Syngnathus scovelli	6.0	30.0	20.9	9.8	11	10.8	32.0	24.0	6.2	44	6.0	32.0	23.4	7.0	55
Leiostomus xanthurus	10.0	30.0	23.6	5.5	47	10.9	32.0	25.7	5.1	82	10.0	32.0	25.0	5.2	129
Gambusia affinis	5.0	33.8	17.4	11.1	29	11.2	32.0	24.4	6.6	17	5.0	33.8	20.0	9.6	46
Fundulus grandis	6.0	33.8	17.6	11.2	34	10.8	32.0	24.7	6.6	21	6.0	33.8	20.3	9.6	55
Arius felis	20.0	30.0	24.6	4.1	25	20.0	32.0	27.0	3.1	72	20.0	32.0	26.4	3.4	97
Mugil cephalus	5.0	30.0	14.7	12.2	55	10.8	31.5	23.6	5.9	29	5.0	31.5	17.7	10.4	84
Lepomis punctatus	5.0	30.0	14.5	12.1	17	10.5	31.8	23.1	6.7	34	5.0	31.8	20.2	8.7	51
Lepomis macrochirus	5.0	30.0	16.7	11.6	16	10.5	31.8	23.9	6.6	32	5.0	31.8	21.5	8.5	48
Cynoscion arenarius	8.0	31.0	26.4	7.1	10	10.9	32.0	25.0	5.4	48	8.0	32.0	25.3	5.7	58
Ictalurus furcatus	7.0	30.0	14.6	9.3	43	10.5	32.0	20.3	8.2	23	7.0	32.0	16.6	8.9	66
Lepomis microlophus	6.0	30.0	16.9	11.4	17	10.5	32.0	23.8	6.1	27	6.0	32.0	21.1	8.4	44
Heterandria formosa	5.0	33.8	20.5	9.3	15	12.0	30.0	22.4	6.8	11	5.0	33.8	21.3	8.2	26
Gobiosoma bosci	7.8	30.0	19.7	10.2	10	10.5	31.0	23.7	6.7	31	7.8	31.8	22.7	7.6	41

*SD = Standard Deviation

Table 23. Turbidity Ranges for the 20 Most Abundant Fish Species in Lake Pontchartrain, LA, estuary, 1978

	January-June					July-December					Year				
	Min.	Max.	Mean	SD*	No. Coll.	Min.	Max.	Mean	SD*	No. Coll.	Min.	Max.	Mean	SD*	No. Coll.
Anchoa mitchilli	1	130	46	45	93	15	195	78	35	131	1	195	65	40	224
Micropogonias undulatus	1	105	39	51	100	20	195	81	32	102	1	195	60	42	202
Brevoortia patronus	1	105	42	41	90	20	140	72	30	57	1	140	53	37	147
Menidia beryllina	2	100	37	46	56	15	160	73	37	64	2	160	56	41	120
Cyprinodon variegatus	2	100	29	39	40	15	160	59	36	29	2	160	41	38	69
Lucania parva	2	100	33	50	39	15	150	74	37	45	2	150	55	43	84
Poecilia latipinna	2	80	26	32	17	15	100	46	25	20	2	100	36	28	37
Syngnathus scovelli	11	100	47	52	11	20	160	86	34	44	11	160	78	38	55
Leiostomus xanthurus	10	105	52	40	47	30	195	81	33	82	10	195	71	35	129
Gambusia affinis	2	80	27	30	29	15	100	49	24	17	2	100	35	27	46
Fundulus grandis	2	80	30	39	34	15	160	61	38	21	2	160	42	38	55
Arius felis	20	105	66	34	25	30	160	84	30	72	20	160	79	31	97
Mugil cephalus	2	100	32	66	55	20	160	93	38	29	2	160	53	58	84
Lepomis punctatus	2	100	27	45	17	15	150	64	35	34	2	150	52	38	51
Lepomis macrochirus	5	100	32	45	16	30	150	69	33	32	5	150	57	37	48
Cynoscion arenarius	17	105	80	30	10	30	195	88	30	48	17	195	87	30	58
Ictalurus furcatus	5	80	25	37	43	20	135	57	33	23	5	135	36	35	66
Lepomis microlophus	5	100	33	47	17	15	150	74	41	27	5	150	58	43	44
Heterandria formosa	5	90	35	33	15	15	100	52	26	11	5	100	42	30	26
Gobiosoma bosci	2	100	47	40	10	15	160	71	36	31	2	160	65	36	41

*SD = Standard Deviation

Table 24. Seasonal Abundance Patterns of Lake Pontchartrain, LA, Marsh Fishes, 1978

	Winter	Spring	Summer	Fall	Dominant season(s)
Dasyatis sabina				1.00 (1)	---
Lepisosteus oculatus	* .21 (18)	* .24 (20)	* .14 (12)	* .41 (34)	2, 3, 4
Lepisosteus osseus			1.00 (1)		---
Lepisosteus spatula	.10 (2)	* .59 (11)	.21 (4)	.10 (2)	2
Amia calva	.27 (4)		.13 (2)	* .60 (9)	4
Elops saurus			* 1.00 (12)		3
Anguilla rostrata			1.00 (3)		---
Alosa chrysochloris	1.00 (1)				---
Brevoortia patronus	# 14	* .97 (1916)	.02 (36)	.01 (18)	2
Dorosoma cepedianum	.22 (7)	.13 (4)	.02 (1)	* .63 (20)	4
Dorosoma petenense	* .83 (30)	.03 (1)	.03 (1)	.11 (4)	1
Anchoa mitchilli	.09 (219)	.08 (199)	* .32 (753)	* .51 (1211)	3, 4
Cyprinus carpio			1.00 (2)		---
Ictalurus furcatus	.04 (10)	* .38 (103)	* .21 (56)	* .37 (101)	2, 3, 4
Ictalurus natalis			1.00 (2)		---
Ictalurus punctatus	* .41 (147)	* .31 (110)	.09 (32)	.19 (66)	1, 2
Pylodictis olivaris				1.00 (2)	---
Arius felis			.07 (1)	* .93 (14)	4
Strongylura marina			.33 (1)	.67 (2)	---
Adinia xenica	* .91 (285)	.09 (30)			1
Cyprinodon variegatus	* .60 (1436)	* .22 (541)	.15 (358)	.03 (76)	1, 2
Fundulus chrysotus		1.00 (1)			
Fundulus grandis	* .76 (544)	* .19 (136)	.05 (32)	# (5)	1, 2
Fundulus jenkinsi	* .79 (166)	* .21 (43)			1, 2
Fundulus pulvereus	* .45 (62)	* .48 (67)	.06 (8)	.01 (2)	1, 2
Lucania parva	* .54 (1153)	.06 (136)	* .22 (466)	* .18 (388)	1, 3, 4
Gambusia affinis	* .48 (604)	* .36 (452)	.10 (131)	.06 (71)	1, 2
Heterandria formosa	* .55 (270)	* .21 (103)	.02 (9)	* .22 (105)	1, 3, 4
Poecilia latipinna	* .26 (587)	* .39 (866)	* .18 (409)	* .17 (378)	1, 2, 3, 4
Labidesthes sicculus				1.00 (2)	---
Menidia beryllina	* .40 (709)	* .35 (610)	.16 (277)	.09 (169)	1, 2
Syngnathus scovelli	* .35 (15)	.02 (1)	.21 (9)	* .42 (18)	1, 4
Morone chrysops				1.00 (1)	---
Morone mississippiensis	1.00 (3)				---
Centrarchus macropterus				1.00 (1)	---
Chaenobryttus gulosus	.07 (1)	* .40 (6)	* .53 (8)		2, 3
Lepomis macrochirus	* .20 (146)	.10 (83)	* .34 (251)	* .36 (268)	1, 3, 4
Lepomis megalotis	.13 (2)		.06 (1)	* .81 (13)	4
Lepomis microlophus	* .37 (151)	* .20 (83)	* .19 (75)	* .24 (96)	1, 2, 3, 4
Lepomis punctatus	.24 (209)	* .16 (139)	* .24 (213)	* .37 (326)	1, 2, 3, 4
Micropterus salmoides	.12 (15)	.02 (3)	* .49 (62)	* .37 (46)	3, 4
Pomoxis nigromaculatus	.04 (1)	.04 (1)	* .75 (17)	.17 (4)	3
Archosargus probatocephalus	1.00 (1)				---
Lagodon rhomboides			.40 (2)	.60 (3)	---
Aplodinotus grunniens	* 1.00 (7)				1
Bairdiella chrysura				1.00 (4)	---
Cynoscion arenarius			.29 (2)	* .71 (5)	4
Cynoscion nebulosus			.05 (2)	* .95 (36)	4
Leiostomus xanthurus		.09 (61)	* .18 (120)	* .73 (476)	3, 4
Micropogonias undulatus	.05 (43)	.10 (82)	* .44 (356)	* .41 (333)	3, 4
Pogonias cromis	1.00 (1)				---
Mugil cephalus	* .77 (193)	.10 (24)	.05 (13)	.08 (20)	1
Gobionellus shufeldti		1.00 (1)			---
Gobiosoma bosci	* .38 (14)	.05 (2)	.14 (5)	* .43 (16)	1, 4
Microgobius gulosus		.09 (1)	* .55 (6)	.36 (4)	3
Microgobius thalassinus	1.00 (1)				---
Paralichthys lethostigma	.50 (3)	.33 (2)	.17 (1)		---
Trinectes maculatus	.04 (3)	* .24 (20)	.01 (1)	* .71 (59)	2, 4

*Dominant season(s); # less than .01.

Table 25. Seasonal abundance Patterns of Lake Pontchartrain, LA, Fishes, 1978

	Winter	Spring	Summer	Fall	Dominant season(s)
Carcharhinus leucas			* 1.00 (26)		3
Dasyatis sabina		.19 (3)	.25 (4)	.56 (9)	4
Rhinoptera bonasus				1.00 (1)	---
Acipenser oxyrhynchus	1.00 (1)				---
Polyodon spathula			1.00 (1)		---
Lepisosteus oculatus		.33 (2)	.50 (3)	.17 (1)	---
Lepisosteus osseus		.14 (1)		* .86 (6)	4
Lepisosteus spatula	.07 (1)	* .64 (9)	.29 (4)		2
Elops saurus		.05 (1)	* .76 (16)	.19 (4)	3
Anguilla rostrata		.06 (1)	.12 (2)	* .82 (14)	4
Alosa chrysochloris	* .27 (57)	* .24 (52)	* .39 (82)	.10 (22)	1, 2, 3
Brevoortia patronus	.03 (300)	* .89 (8054)	.07 (603)	.01 (119)	2
Dorosoma cepedianum	* .40 (64)	* .38 (59)	.04 (6)	.18 (28)	1, 2
Dorosoma petenense	* .23 (43)	.05 (10)	.06 (12)	* .66 (123)	1, 4
Anchoa hepsetus			1.00 (6)		---
Anchoa mitchilli	.05 (1185)	.12 (2726)	* .35 (7693)	* .48 (10463)	3, 4
Notemigonus crysoleucas				1.00 (2)	---
Carpiodes carpio	1.00 (2)				---
Ictalurus furcatus	* .56 (152)	* .30 (80)	.07 (18)	.07 (20)	1, 2
Ictalurus punctatus	* .48 (29)	.37 (22)	.03 (2)	.12 (7)	1, 2
Pylodictis olivaris	.20 (1)	.80 (4)			---
Arius felis		.07 (83)	* .34 (376)	* .59 (650)	3, 4
Bagre marinus		.09 (3)	* .50 (17)	* .41 (14)	3, 4
Gobiesox strumosus		.01 (1)	* .39 (67)	* .60 (103)	3, 4
Strongylura marina	.01 (1)	.09 (12)	* .55 (70)	* .35 (45)	3, 4
Adinia xenica	1.00 (1)				---
Cyprinodon variegatus	* .24 (394)	* .22 (355)	* .53 (872)	.01 (23)	1, 2, 3
Fundulus chrysotus				1.00 (1)	---
Fundulus grandis	.16 (118)	.06 (45)	* .71 (513)	.07 (47)	3
Fundulus pulvereus	* .41 (12)	* .59 (17)			1, 2
Fundulus similis		1.00 (3)			---
Lucania parva	.17 (163)	.11 (105)	* .51 (476)	* .21 (194)	3, 4
Gambusia affinis	* .44 (227)	.03 (17)	* .53 (274)	# (2)	1, 3, 4
Heterandria formosa	* .44 (15)	* .21 (7)	.06 (2)	* .29 (10)	1, 2, 4
Poecilia latipinna	* .56 (297)	.02 (9)	* .41 (217)	.01 (8)	1, 3
Membras martinica	.01 (1)		* .93 (182)	.06 (12)	3
Menidia beryllina	* .22 (1325)	* .17 (1039)	* .37 (2261)	* .24 (1496)	1, 2, 3, 4
Syngnathus louisianae			* .74 (65)	* .26 (23)	3, 4
Syngnathus scovelli	.03 (76)	.01 (12)	* .38 (834)	* .58 (1297)	3, 4
Morone mississippiensis	1.00 (3)				---
Chaenobryttus gulosus	1.00 (1)				---
Lepomis macrochirus	.08 (5)		* .45 (30)	* .47 (31)	3, 4
Lepomis microlophus	.02 (3)		* .26 (34)	* .72 (95)	3, 4
Lepomis punctatus	.14 (6)		* .34 (15)	* .52 (23)	3, 4
Micropterus salmoides	.03 (2)	.01 (1)	* .49 (36)	* .47 (34)	3, 4
Caranx hippos			.50 (1)	.50 (1)	---
Oligoplites saurus			.17 (4)	* .83 (20)	4
Archosargus probatocephalus	* .24 (26)	* .15 (17)	* .34 (37)	* .27 (30)	1, 2, 3, 4
Lagodon rhomboides		.07 (3)	* .75 (33)	.18 (8)	3
Aplodinotus grunniens	* .53 (8)	* .40 (6)		.07 (1)	1, 2
Bairdiella chrysura		.02 (1)	* .58 (25)	* .40 (17)	3, 4
Cynoscion arenarius	.07 (39)	# (1)	* .68 (386)	* .24 (144)	3, 4
Cynoscion nebulosus	.18 (54)	.07 (22)	* .34 (106)	* .41 (126)	3, 4
Leiostomus xanthurus	.03 (42)	.44 (610)	* .39 (534)	.14 (193)	2, 3
Menticirrhus americanus	.20 (1)	.20 (1)		.60 (3)	---
Micropogonias undulatus	.09 (1057)	* .20 (2304)	* .43 (4849)	* .28 (3157)	2, 3, 4
Pogonias cromis	* .16 (18)	* .48 (53)	* .16 (17)	* .20 (22)	1, 2, 3, 4
Sciaenops ocellata	* .32 (9)	.14 (4)	.11 (3)	* .43 (12)	1, 4
Chaetodipterus faber				1.00 (2)	---
Mugil cephalus	* .24 (163)	* .41 (279)	* .31 (212)	.04 (34)	1, 2, 3
Polydactylus octonemus			.50 (3)	.50 (3)	
Astroscopus y-graecum				1.00 (2)	---
Chasmodes bosquianus				1.00 (2)	---
Dormitator maculatus	.11 (3)		* .89 (24)		3
Gobionellus boleosoma				* 1.00 (11)	4
Gobionellus shufeldti		.50 (1)	.50 (1)		---
Gobiosoma bosci	.01 (6)	.03 (16)	* .50 (234)	* .46 (214)	3, 4
Microgobius gulosus		* .33 (7)	.15 (3)	* .42 (11)	2, 4
Prionotus tribulus				* 1.00 (7)	4
Citharichthys spilopteura			* .67 (8)	.33 (4)	3
Paralichthys lethostigma	.16 (3)	* .42 (8)		* .42 (8)	2, 4
Trinectes maculatus	* .43 (151)	* .26 (93)	* .26 (94)	.05 (19)	1, 2, 3
Symphurus plagiusa				* 1.00 (13)	4
Monacanthus hispidus				1.00 (1)	---
Sphoeroides parvus	.50 (1)			.50 (1)	---

*Dominant season(s); # less than .01.

Table 26. Faunal Comparison between Lake Pontchartrain, LA, and Surrounding Marsh Area, 1978

	Species	1978 Total Lake	Marsh	% Lake	% Marsh	Area Group
1	C. leucas	26	0	100	0	LAKE ONLY
2	R. bonasus	1	0	100	0	
3	A. oxyrhynchus	1	0	100	0	
4	P. spathula	1	0	100	0	
5	A. hepsetus	6	0	100	0	
6	N. crysoleucas	2	0	100	0	
7	C. carpio	2	0	100	0	
8	B. marinus	34	0	100	0	
9	G. strumosus	171	0	100	0	
10	F. similis	3	0	100	0	
11	M. martinica	195	0	100	0	
12	S. louisianae	88	0	100	0	
13	C. hippos	2	0	100	0	
14	O. saurus	24	0	100	0	
15	M. americanus	5	0	100	0	
16	S. ocellata	28	0	100	0	
17	C. faber	2	0	100	0	
18	P. octonemus	6	0	100	0	
19	A. y-graecum	2	0	100	0	
20	C. bosquianus	2	0	100	0	
21	D. maculatus	27	0	100	0	
22	G. boleosoma	11	0	100	0	
23	P. tribulus	7	0	100	0	
24	C. spilopterus	12	0	100	0	
25	S. plagiusa	13	0	100	0	
26	M. hispidus	1	0	100	0	
27	S. parvus	2	0	100	0	
28	A. chrysochloris	213	1	99	1	PREDOMINANTLY LAKE
29	A. felis	1109	15	99	1	
30	A. probatocephalus	110	1	99	1	
31	C. arenarius	570	7	99	1	
32	P. cromis	110	1	99	1	
33	S. marina	128	3	98	2	
34	S. scovelli	2219	43	98	2	
35	D. sabina	16	1	94	6	
36	M. undulatus	11367	814	93	7	
37	G. bosci	470	37	93	7	
38	B. chrysura	43	4	91	9	
39	A. mitchilli	22067	2384	90	10	
40	L. rhomboides	44	5	90	10	
41	C. nebulosus	308	38	89	11	
42	L. osseus	7	1	88	12	
43	A. rostrata	17	3	85	15	
44	D. petenense	188	36	84	16	
45	D. cepedianum	157	32	83	17	

Table 26. (Continued)

	Species	1978 Total Lake	1978 Total Marsh	% Lake	% Marsh	Area Group
46	B. patronus	9076	1984	82	18	
47	T. maculatus	357	83	81	19	
48	M. beryllina	6121	1765	78	22	
49	P. lethostigma	19	6	76	24	
50	M. cephalus	688	250	73	27	
51	P. olivaris	5	2	71	29	
52	A. grunniens	15	7	68	32	
53	L. xanthurus	1379	657	68	32	
54	G. shufeldti	2	1	67	33	
55	M. gulosus	21	11	66	34	LAKE & MARSH
56	E. saurus	21	12	64	36	
57	I. furcatus	270	270	50	50	
58	F. chrysotus	1	1	50	50	
59	F. grandis	723	717	50	50	
60	M. mississippiensis	3	3	50	50	
61	L. spatula	14	19	42	58	
62	C. variegatus	1644	2411	41	59	
63	M. salmoides	73	126	37	63	
64	L. parva	938	2143	30	70	PREDOMINANTLY MARSH
65	G. affinis	520	1258	29	71	
66	L. microlophus	137	405	25	75	
67	P. latipinna	531	2240	19	81	
68	F. pulvereus	29	139	14	86	
69	I. punctatus	60	355	14	86	
70	L. macrochirus	61	748	8	92	
71	L. oculatus	6	84	7	93	
72	H. formosa	34	487	7	93	
73	C. gulosus	1	15	6	94	
74	L. punctatus	44	887	5	95	
75	A. xenica	1	315	1	99	
76	A. calva	0	15	0	100	MARSH
77	C. carpio	0	2	0	100	
78	I. natalis	0	2	0	100	
79	F. jenkinsi	0	209	0	100	
80	L. sicculus	0	2	0	100	
81	M. chrysops	0	1	0	100	
82	C. macropterus	0	1	0	100	
83	L. megalotis	0	16	0	100	
84	P. nigromaculatus	0	23	0	100	
85	M. thalassinus	0	1	0	100	

Table 27. Lake Pontchartrain Community Diversity Parameters by Month, 1978*

LAKE	J	F	M	A	M	J	J	A	S	O	N	D
H	3.095 (2.145)	2.580 (1.788)	2.918 (2.022)	2.285 (1.584)	1.963 (1.361)	3.387 (2.348)	2.630 (1.823)	3.043 (2.109)	2.579 (1.788)	2.353 (1.631)	2.033 (1.409)	3.680 (2.551)
D	2.700 (1.871)	2.204 (1.528)	2.330 (1.615)	2.520 (1.747)	2.451 (1.699)	3.585 (2.485)	3.070 (2.128)	3.442 (2.386)	3.702 (2.566)	3.413 (2.366)	3.814 (2.643)	3.072 (2.129)
E	0.444	0.320	0.393	0.212	0.156	0.326	0.220	0.267	0.167	0.159	0.102	0.514
J	0.651 (0.451)	0.556 (0.385)	0.607 (0.421)	0.453 (0.314)	0.393 (0.272)	0.613 (0.425)	0.491 (0.340)	0.554 (0.384)	0.462 (0.320)	0.431 (0.299)	0.362 (0.251)	0.706 (0.489)

MARSH	J	F	M	A	M	J	J	A	S	O	N	D
H	2.752 (1.907)	3.529 (2.446)	3.840 (2.662)	2.440 (1.691)	2.466 (1.709)	3.608 (2.501)	3.023 (2.095)	3.379 (2.342)	2.881 (1.997)	4.188 (2.903)	2.919 (2.023)	3.406 (2.361)
D	1.935 (1.341)	2.571 (1.782)	2.552 (1.769)	2.407 (1.668)	1.768 (1.225)	3.215 (2.228)	3.074 (2.131)	2.135 (1.480)	2.294 (1.590)	3.427 (2.375)	3.142 (2.178)	2.691 (1.865)
E	0.391	0.586	0.750	0.259	0.381	0.581	0.333	0.625	0.400	0.750	0.314	0.500
J	0.608 (0.421)	0.727 (0.504)	0.799 (0.554)	0.513 (0.356)	0.562 (0.390)	0.728 (0.505)	0.599 (0.415)	0.737 (0.511)	0.620 (0.430)	0.810 (0.561)	0.569 (0.394)	0.694 (0.481)

*$\log_2$ units are "bits", $\log_e$ units are "nats"; $\log_e X = .6931 (\log_2 X)$; $\log_e$ value shown below $\log_2$ value.

Table 28. Seasonal Comparison of Community Diversity for Lake Pontchartrain and Surrounding Marsh Area, 1978

LAKE

	1 WINTER	2 SPRING	3 SUMMER	4 FALL
H	3.554	2.399	3.122	2.428
D	3.422	3.148	3.615	4.221
E	0.386	0.156	0.226	0.115
J	0.651	0.437	0.545	0.409
S	44	45	53	61
N	6,066	16,142	21,410	18,993

MARSH

	1 WINTER	2 SPRING	3 SUMMER	4 FALL
H	3.706	3.379	3.722	3.712
D	2.893	2.637	3.537	3.222
E	0.500	0.441	0.442	0.475
J	0.706	0.664	0.686	0.697
S	38	34	43	40
N	7,077	5,858	3,754	4,408

*Lines over seasons indicate significant seasonal difference (.05% level) in N/S ratio. Difference in lake between 1&2, 1&3, 1&4; difference in marsh between 1&3, 2&3.

Note: winter = Dec., Jan., and Feb.; spring = Mar., Apr., and May; summer = June, July, and Aug,; fall = Sept., Oct., and Nov.

Table 29. Comparison of Community Diversity Values: Certain Estuarine Areas from Atlantic and Gulf Coast of United States[a]

AREA	REFERENCE	SEASON	DIVERSITY ($\bar{H}$)[b]
Aransas Bay, Texas	Miller 1965	Summer	2.09 (see Bechtel and Copeland 1970)
Aransas Bay, Texas	Moore 1978	Yearly	3.00 - 3.58 (8 year range)
Corpus Christi Bay, Texas	Bechtel and Copeland 1970	Summer	1.52
Redfish Bay, Texas	Bechtel and Copeland 1970	Summer	1.33
Galveston Bay, Texas	Bechtel and Copeland 1970	Yearly	0.89 - 1.60 (entire bay)
Lake Pontchartrain, La.	Present Study	Yearly	
Lake			1.36 - 2.55 (Yearly $\bar{X}$ = 1.88)
Marsh			1.69 - 2.90 (Yearly $\bar{X}$ = 2.22)
Apalachicola Bay, Florida	Livingston 1976	Yearly	1.12 (average)
St. Marks River marsh, Florida	Subrahmanyam and Drake 1975	Yearly	~0 - 2.0 (intertidal creek)
Wakulla River marsh, Florida	Subrahmanyam and Drake 1975	Yearly	~0 - 1.8 (intertidal creek)
Sapalo and St. Catherine Sound, Georgia	Dahlberg and Odum 1970	Yearly	0.7 - 1.6 (sound only)
North Inlet, South Carolina	Cain and Dean 1976	Yearly	2.0 - 2.4 (intertidal creek)
Cape Fear, North Carolina	Copeland and Birkhead 1972	Yearly	2.02 (average)
Beaufort Inlet, North Carolina	Adams 1976	Yearly	0.23 - 1.52
Patuxent Estuary, Maryland	McErlean et al. 1973	Yearly	~0.3 - 1.7 (4 year range)
Narragansett Bay, Rhode Island	Oviatt and Nixon 1973	Yearly	1.5 - 3.25
Mystic River, Massachusetts	Haedrich and Haedrich 1974	Yearly	0.33 - 1.03

[a]Modified from Table 3, Moore (1978).

[b]Corrected to $\log_e$ where necessary.

APPENDIX

Monthly Distribution of Species

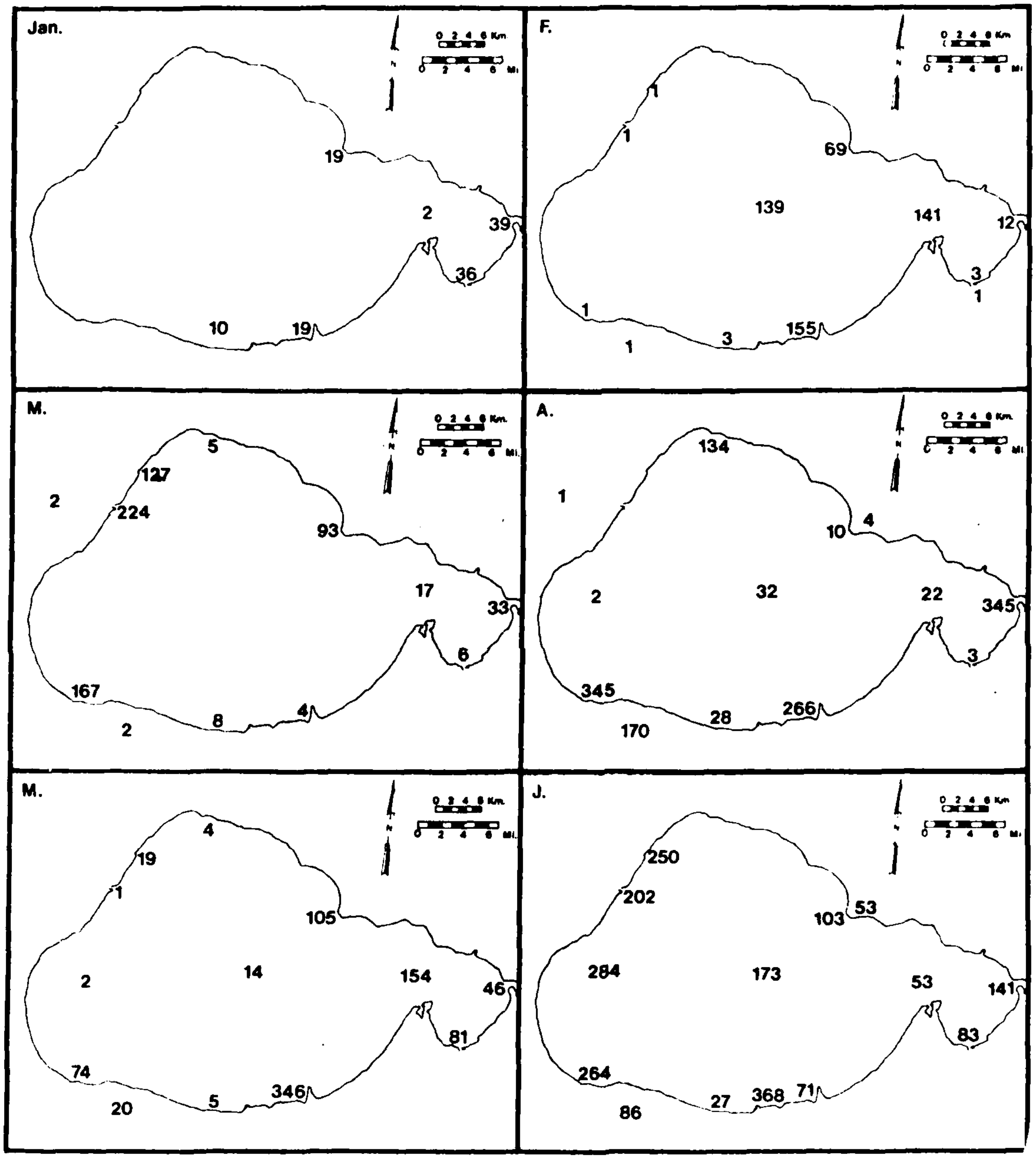

Figure 16A. Monthly distribution (Jan-June) of Anchoa mitchilli in Lake Pontchartrain, LA,1978.

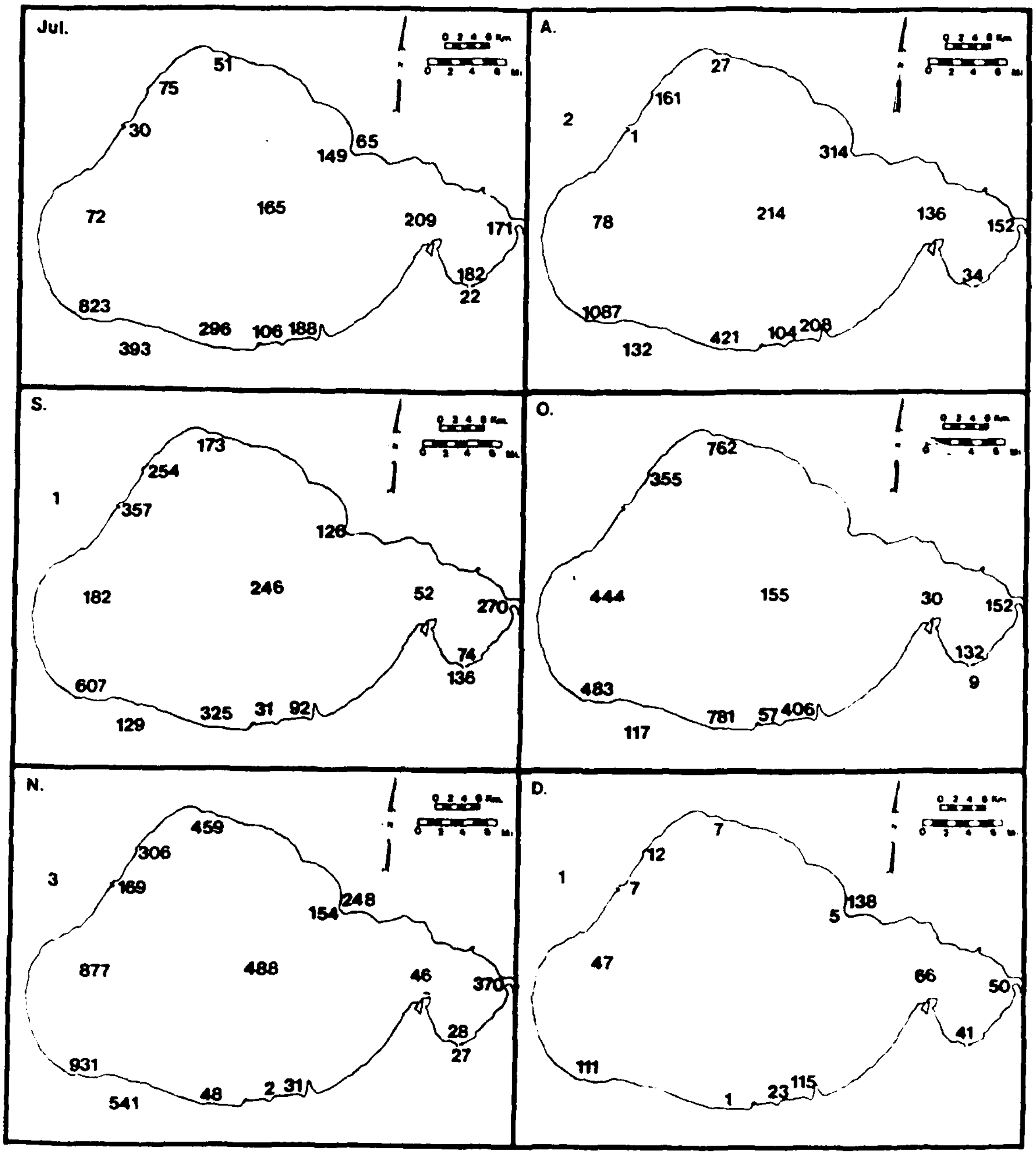

Figure 16B. Monthly distribution (July-Dec) of Anchoa mitchilli in Lake Pontchartrain, LA, in 1978.

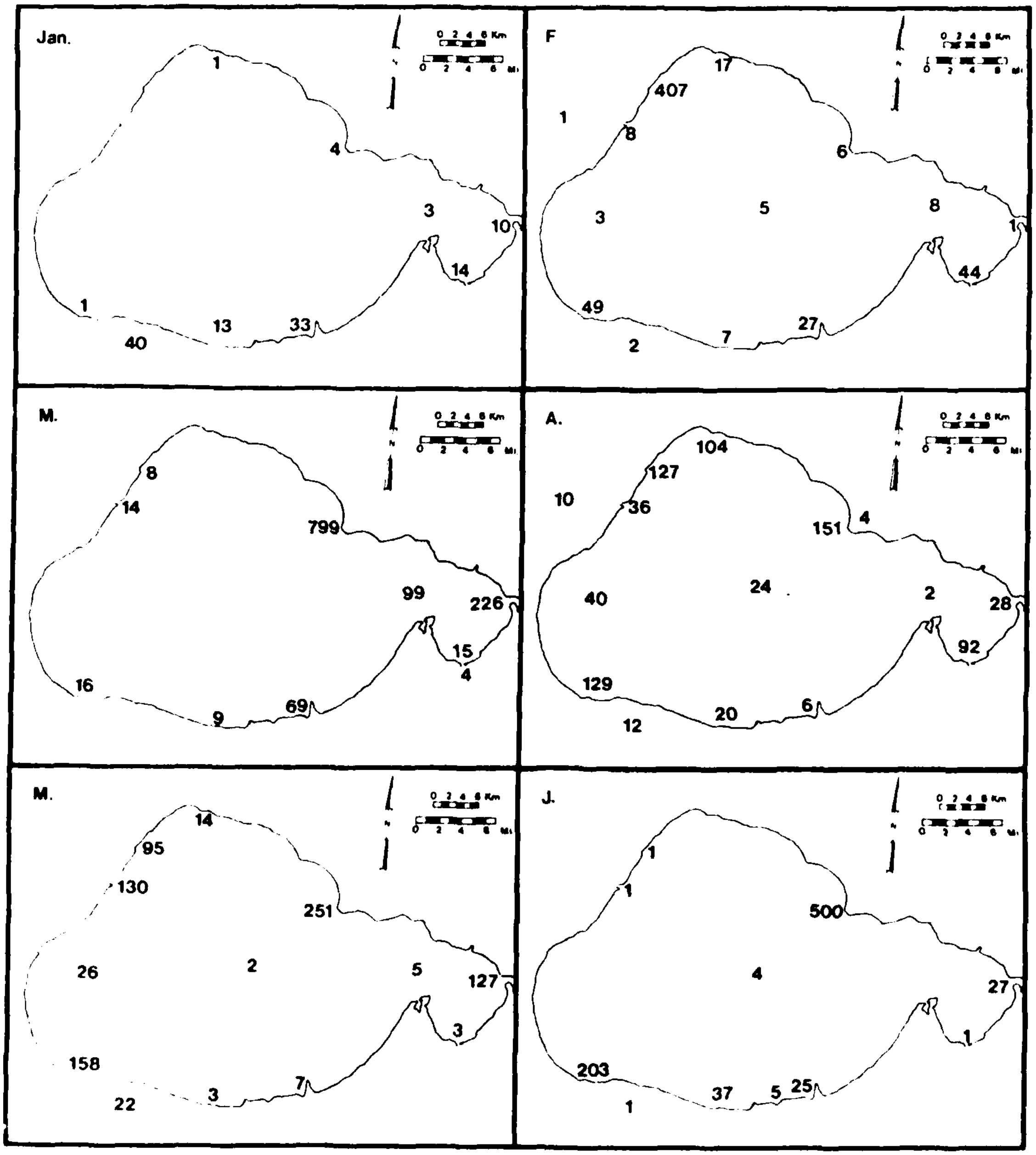

Figure 17A. Monthly distribution (Jan-June) of Micropogonias undulatus in Lake Pontchartrain, LA, in 1978.

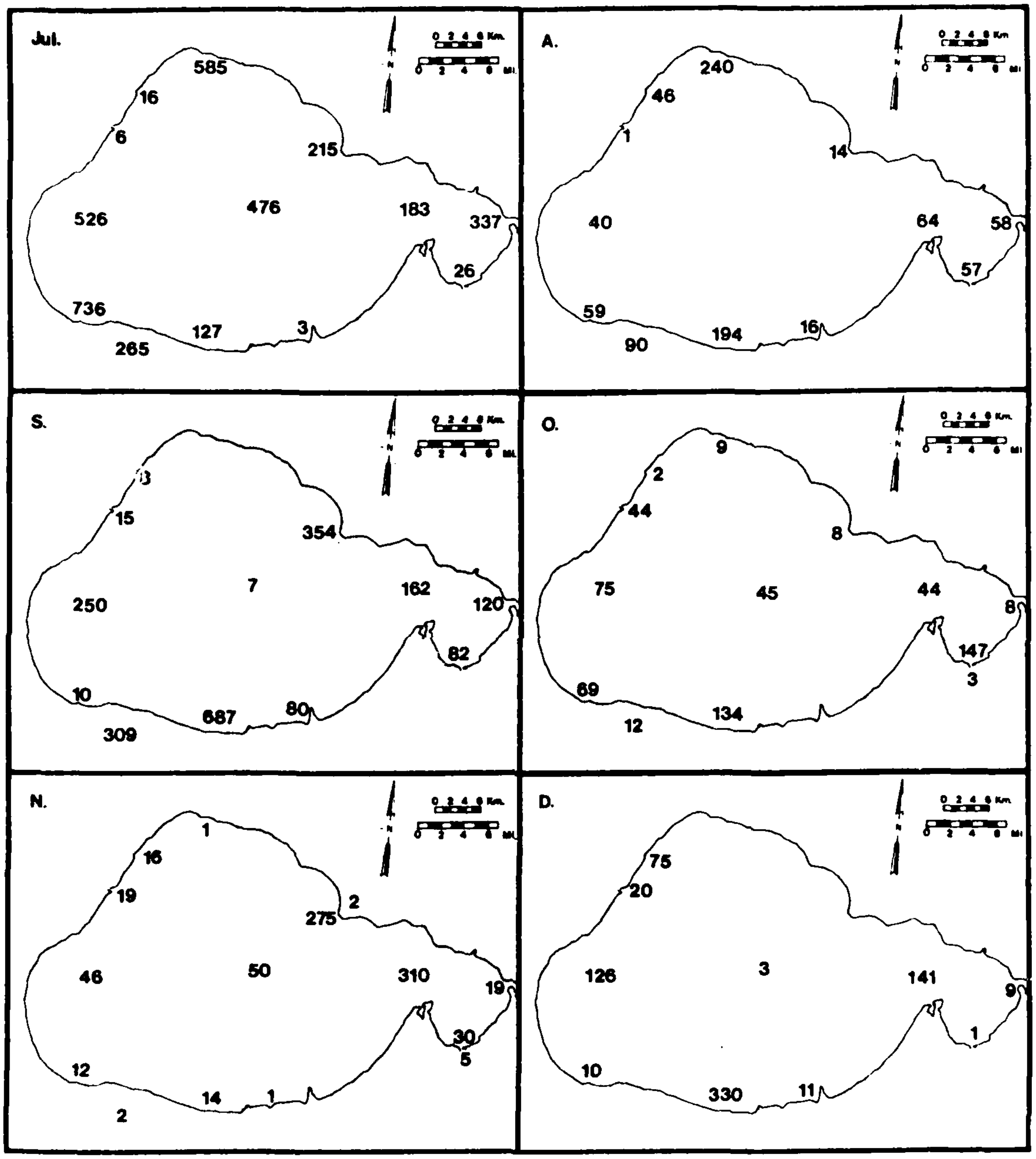

Figure 17B. Monthly distribution (July-Dec) of Micropogonias undulatus in Lake Pontchartrain, LA, in 1978.

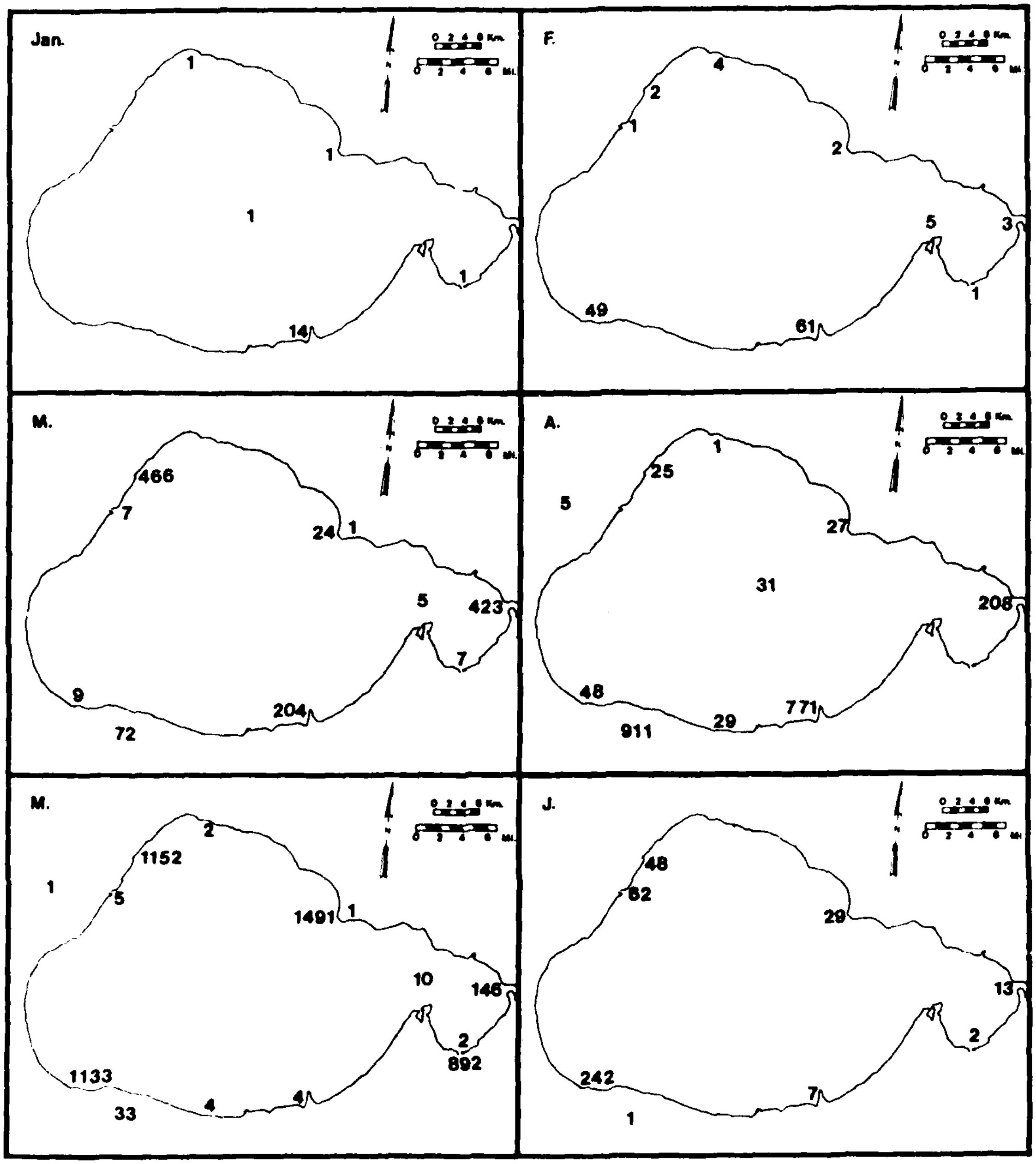

Figure 18A. Monthly distribution (Jan-June) of Brevoortia patronus in Lake Pontchartrain, LA, in 1978.

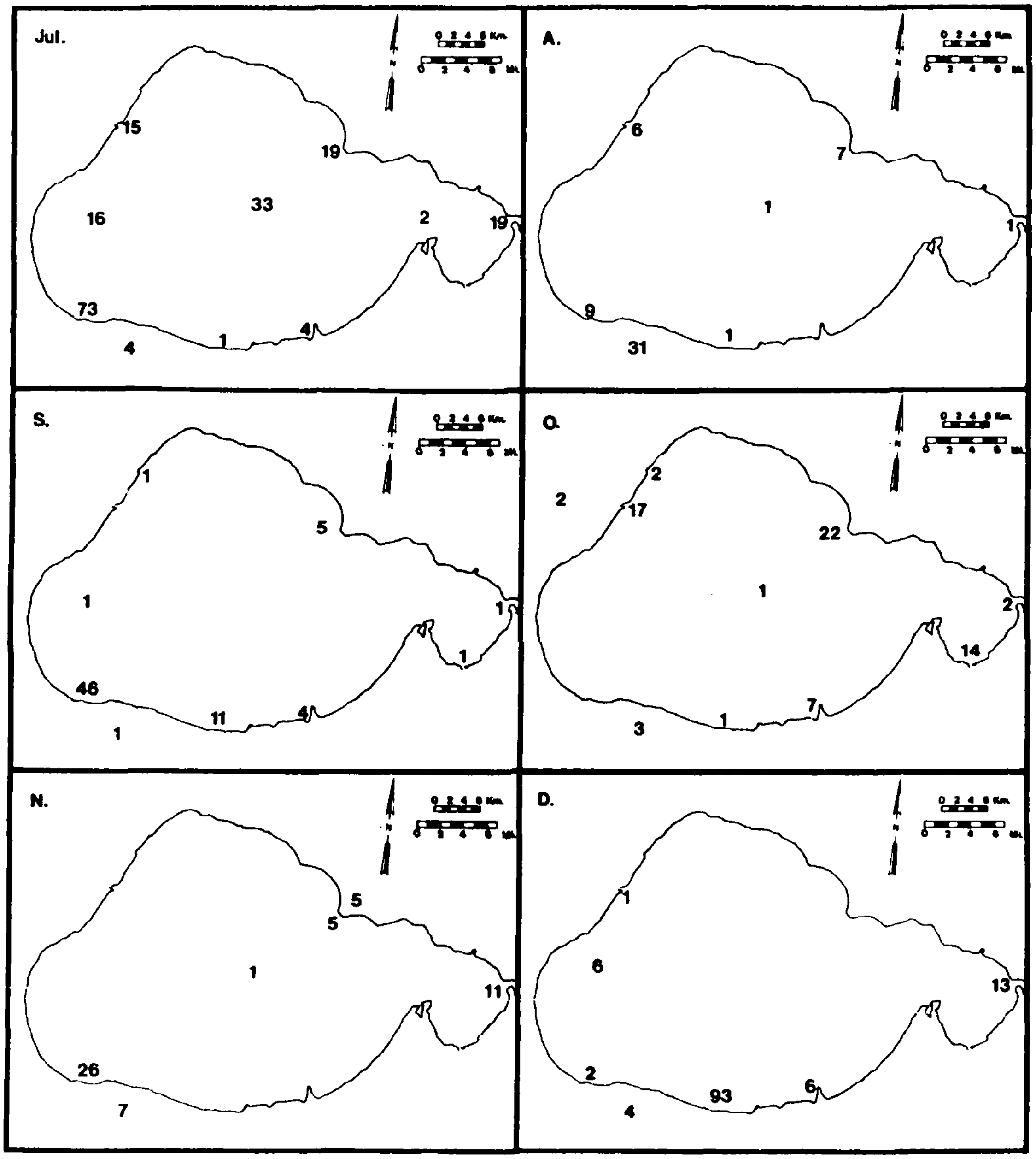

Figure 18B. Monthly distribution (July-Dec) of Brevoortia patronus in Lake Pontchartrain, LA, in 1978.

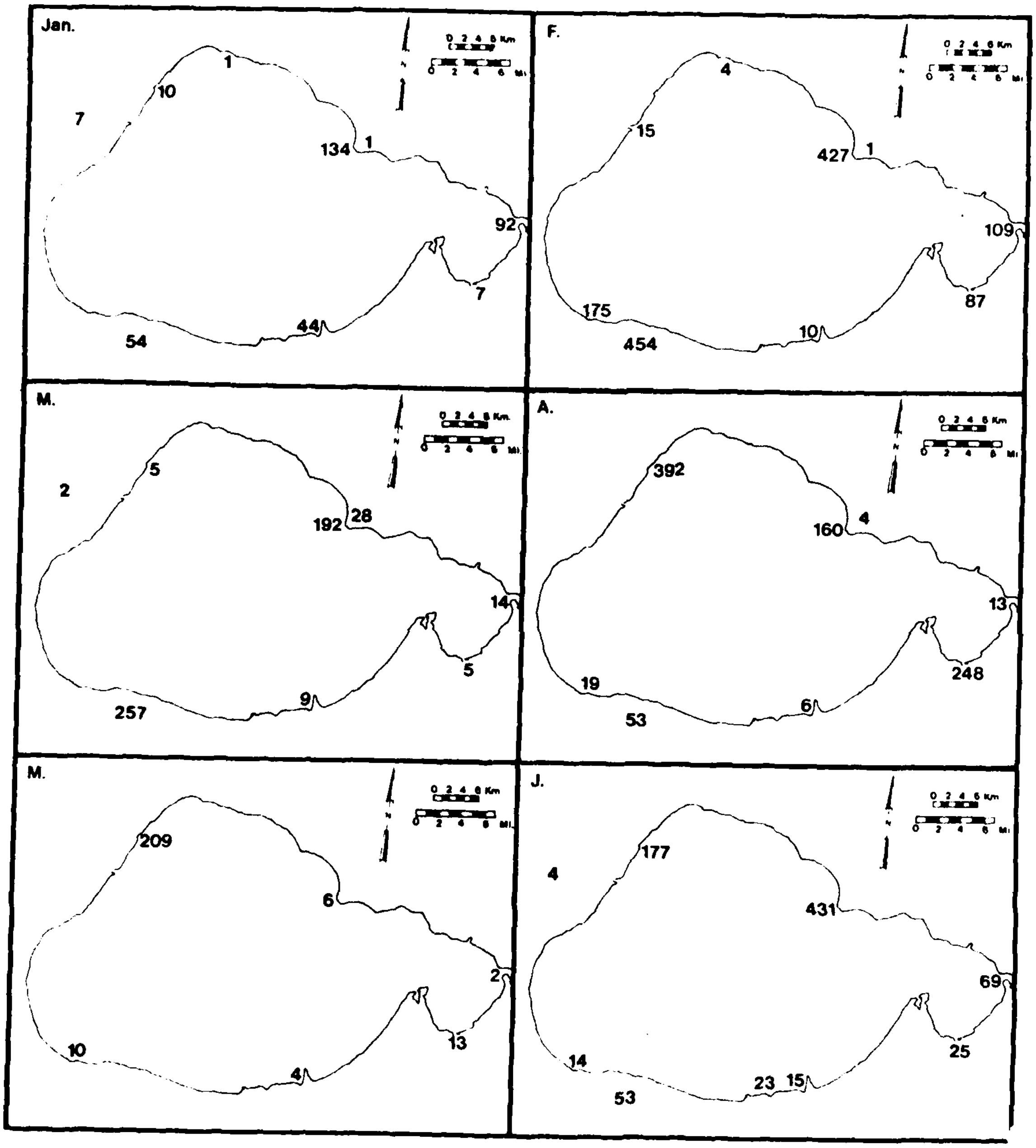

Figure 19A. Monthly distribution (Jan-June) of <u>Menidia beryllina</u> in Lake Pontchartrain, LA, in 1978.

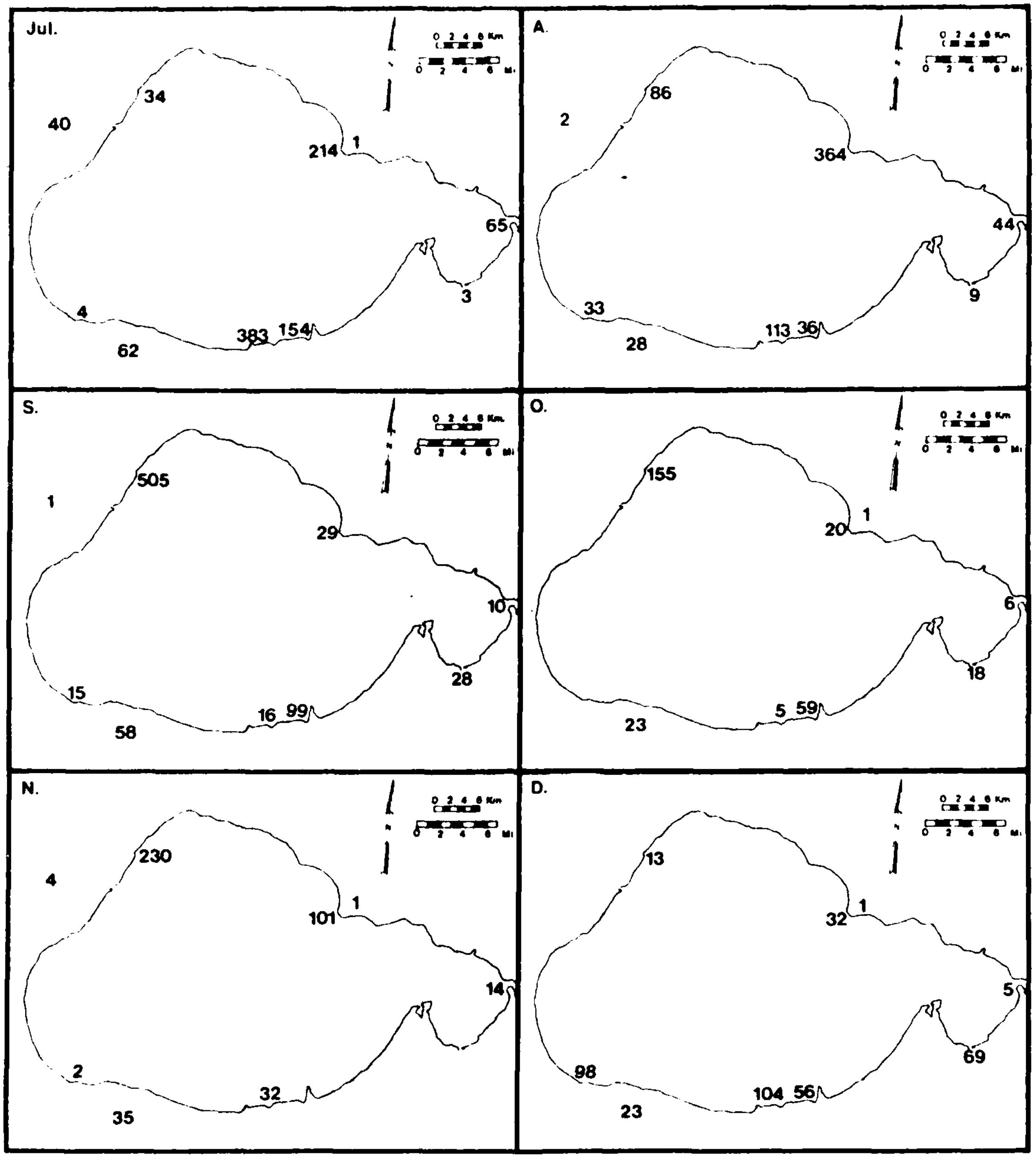

Figure 19B. Monthly distribution (July-Dec) of Menidia beryllina in Lake Pontchartrain, LA, in 1978.

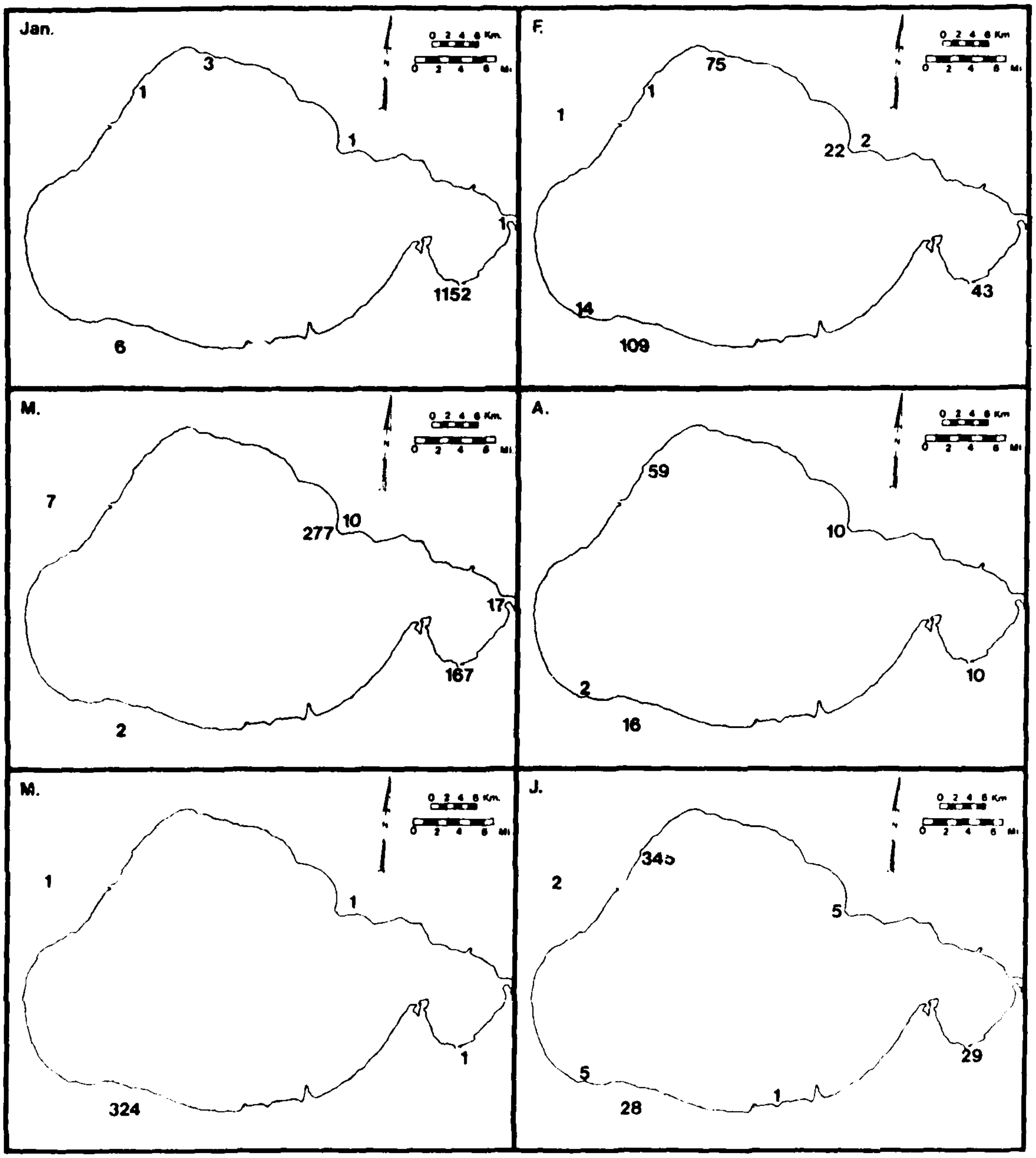

Figure 20A. Monthly distribution (Jan-June) of <u>Cyprinodon variegatus</u> in Lake Pontchartrain, LA, in 1978.

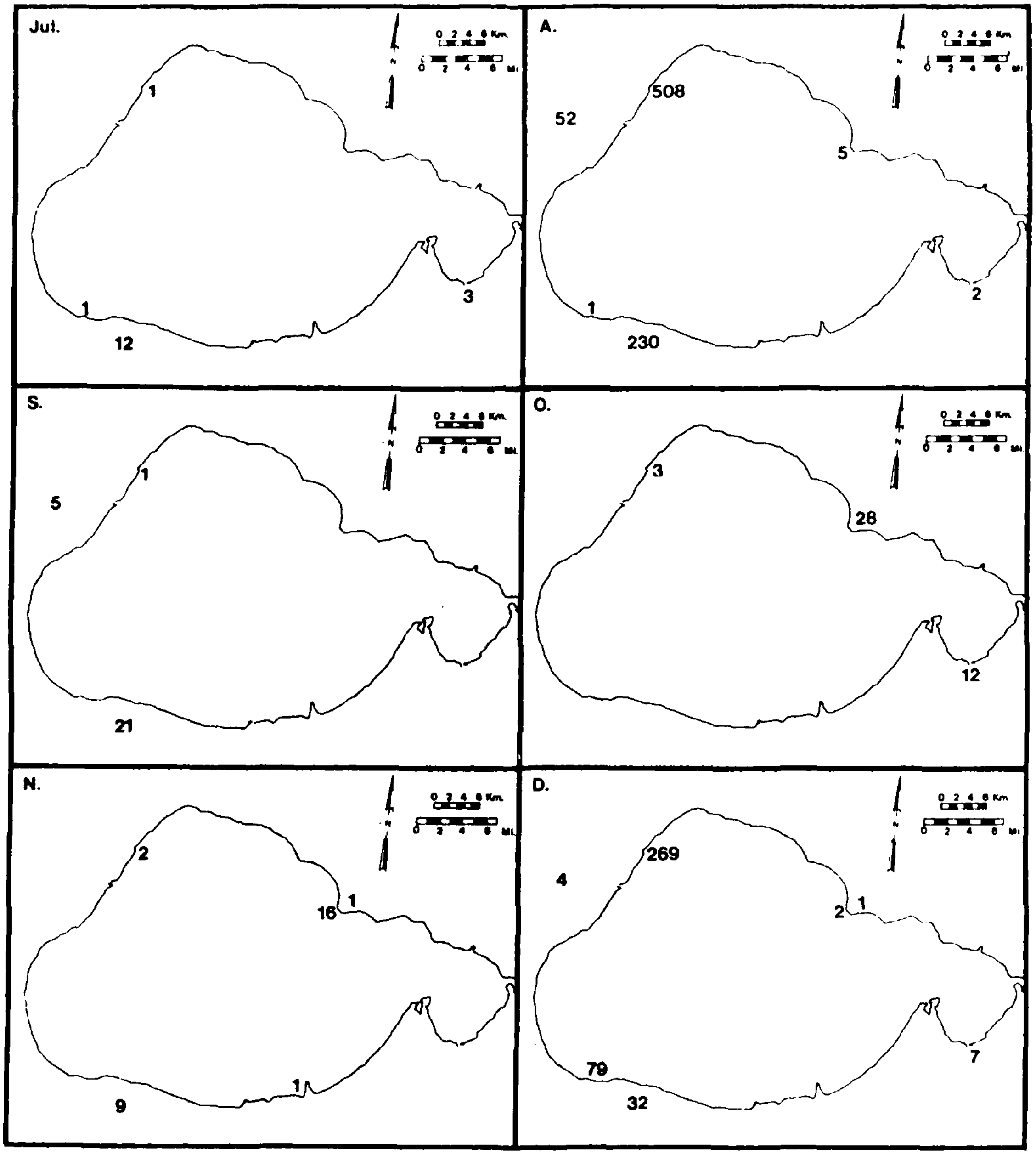

Figure 20B. Monthly distribution (July-Dec) of <u>Cyprinodon variegatus</u> in Lake Pontchartrain, LA, in 1978.

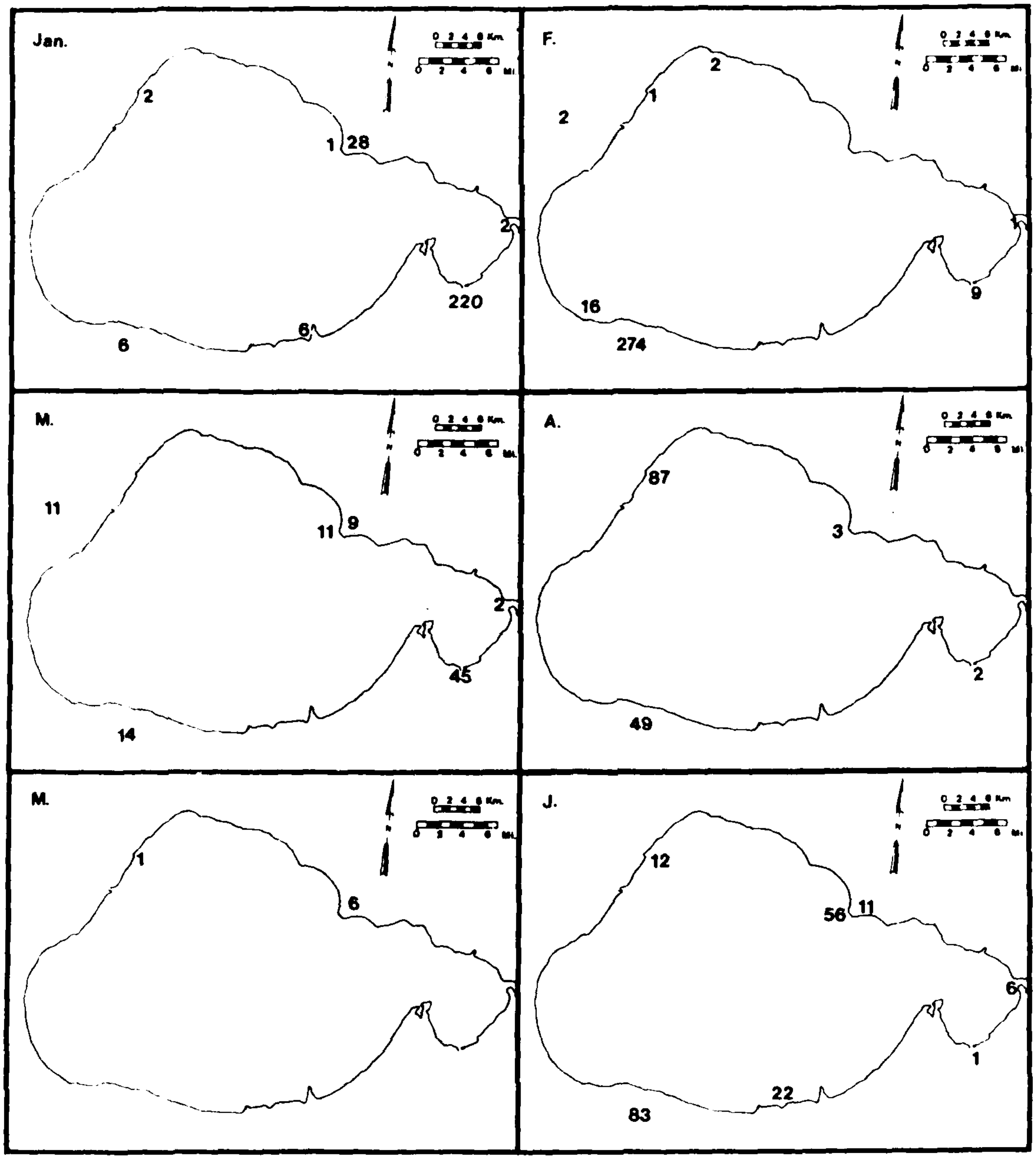

Figure 21A. Monthly distribution (Jan-June) of Lucania parva in Lake Pontchartrain, LA, in 1978.

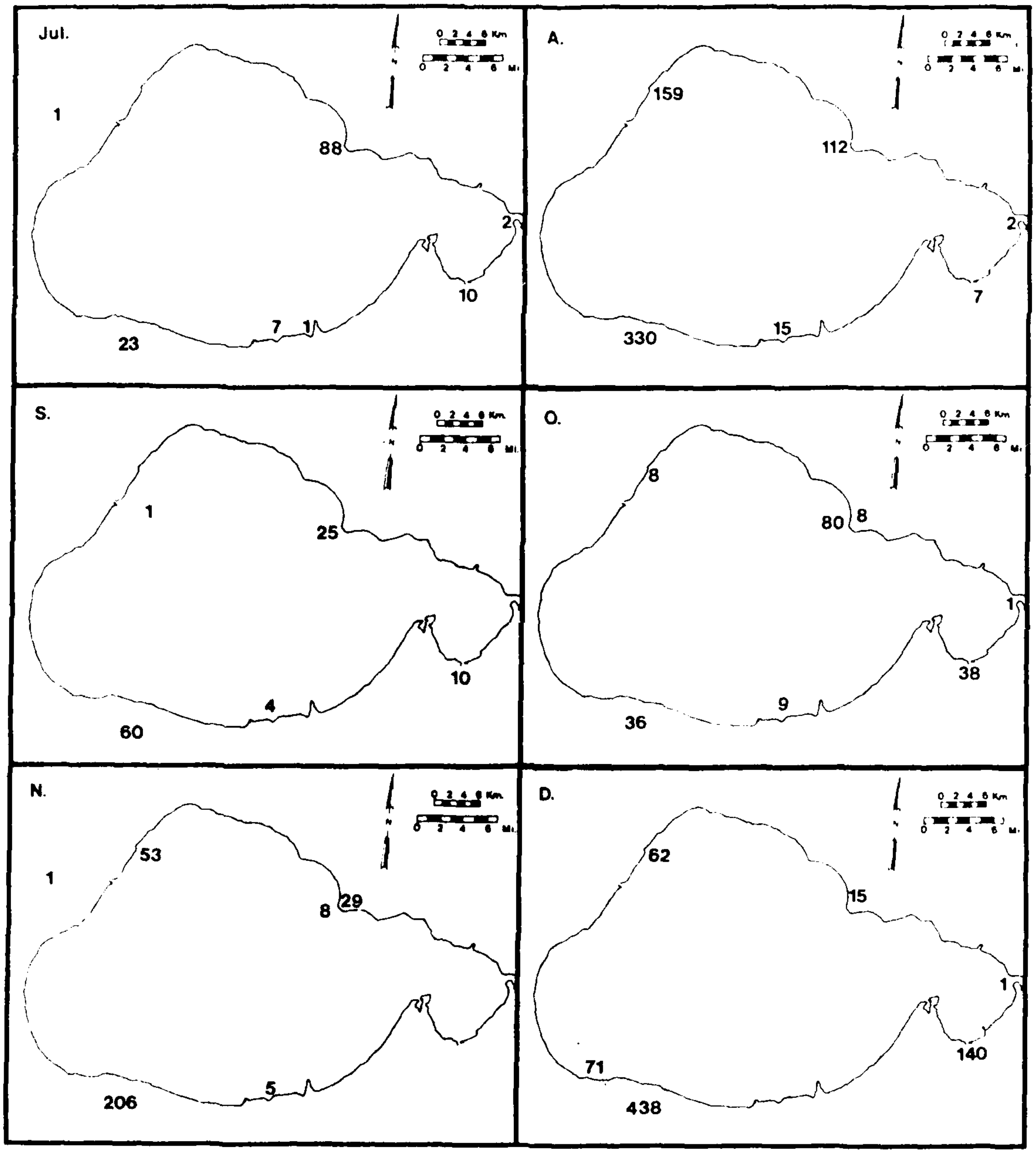

Figure 21B. Monthly Distribution (July-Dec) of <u>Lucania parva</u> in Lake Pontchartrain, LA, in 1978.

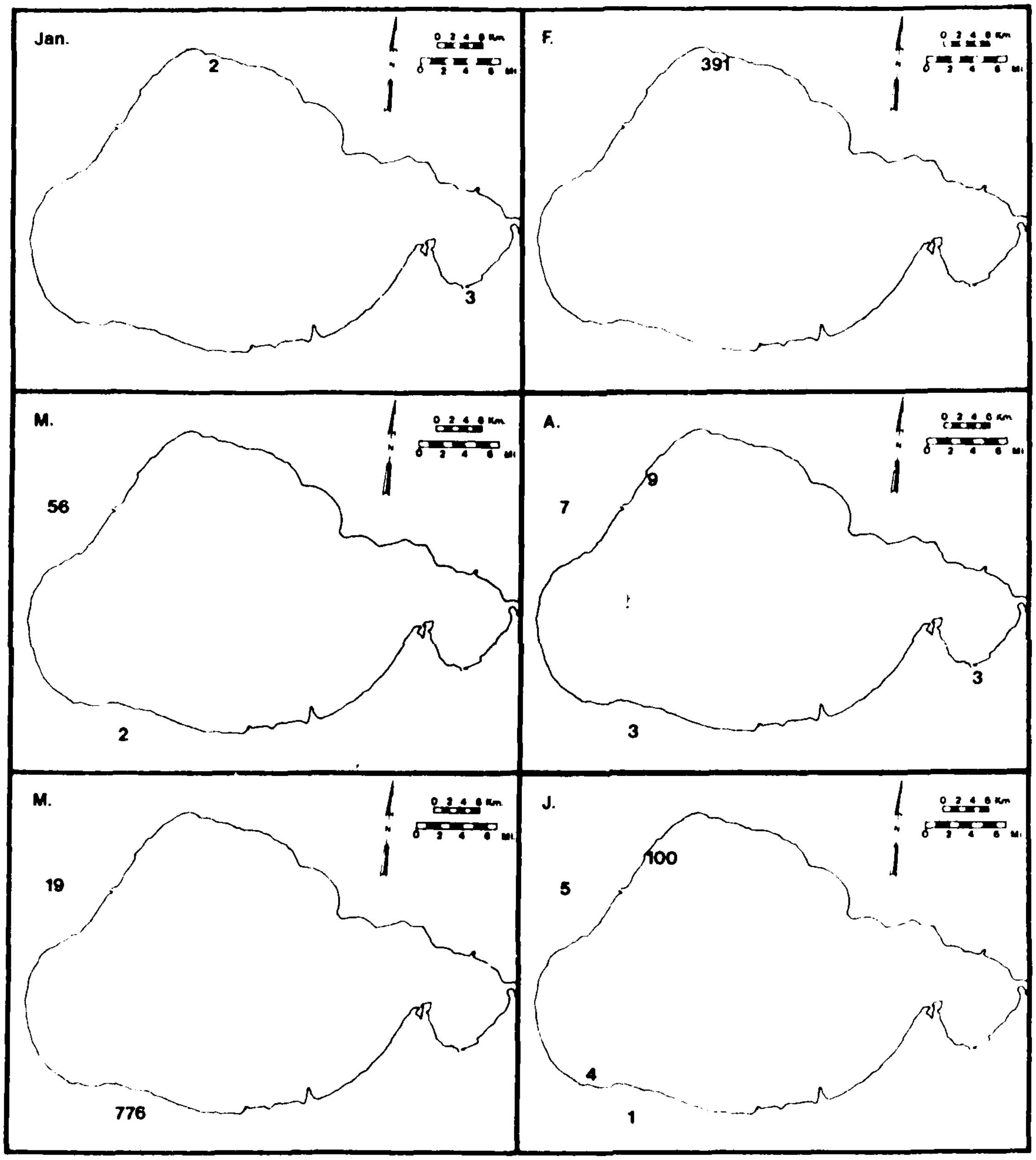

Figure 22A. Monthly distribution (Jan-June) of Poecilia latipinna in Lake Pontchartrain, LA, in 1978.

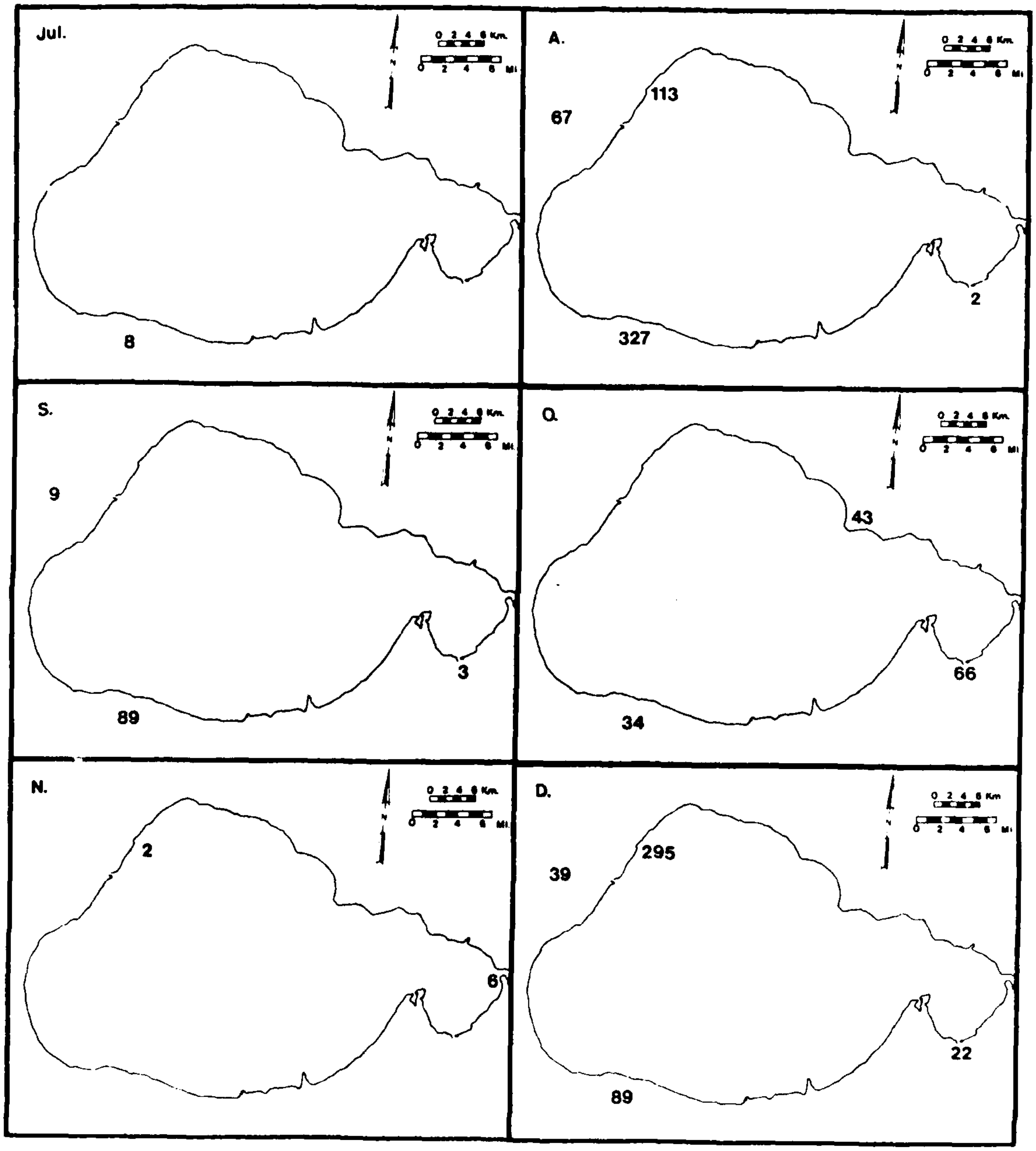

Figure 22B. Monthly distribution (July-Dec) of Poecilia latipinna in Lake Pontchartrain, LA, in 1978.

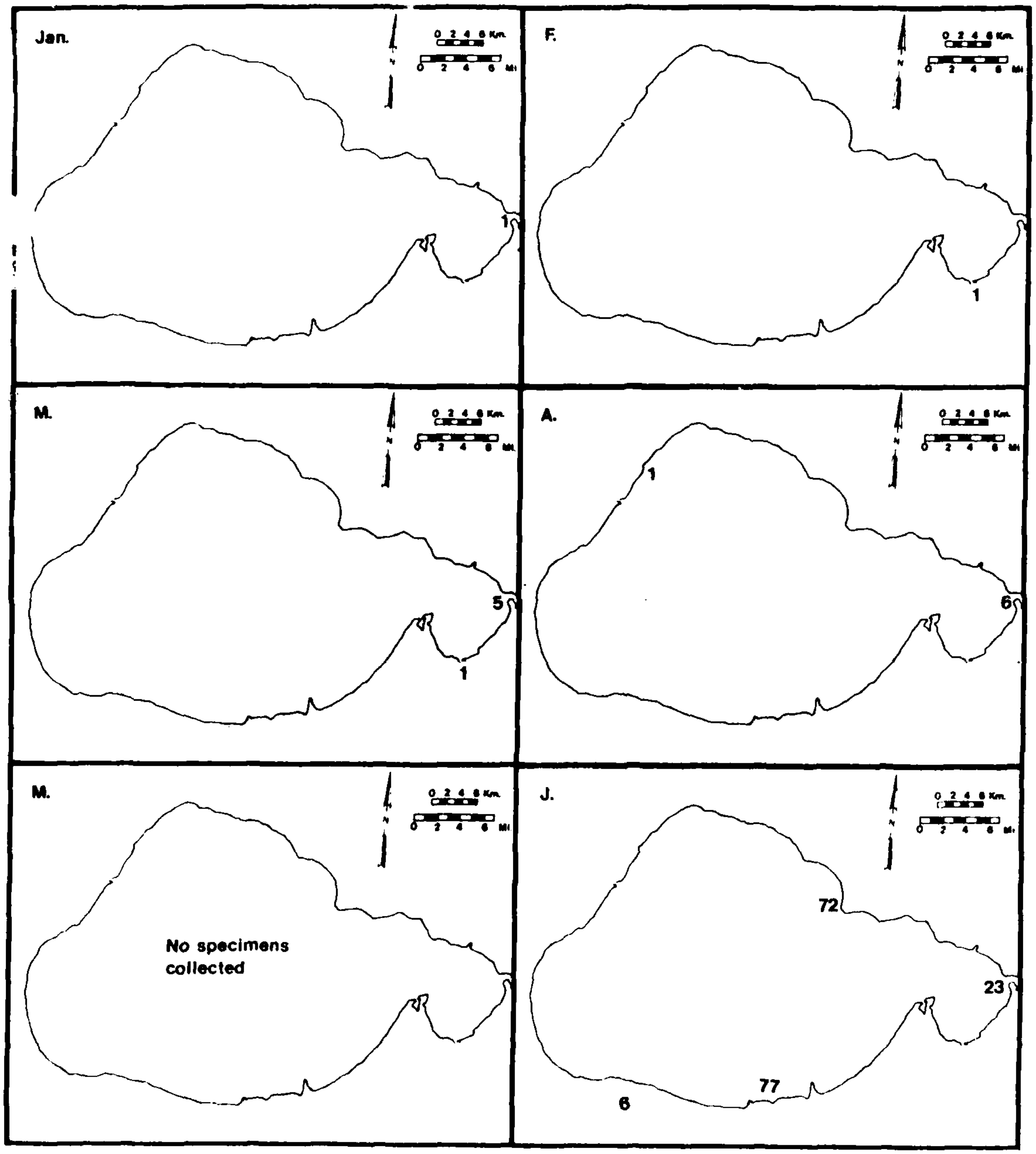

Figure 23A. Monthly distribution (Jan-June) of Syngnathus scovelli in Lake Pontchartrain, LA, in 1978.

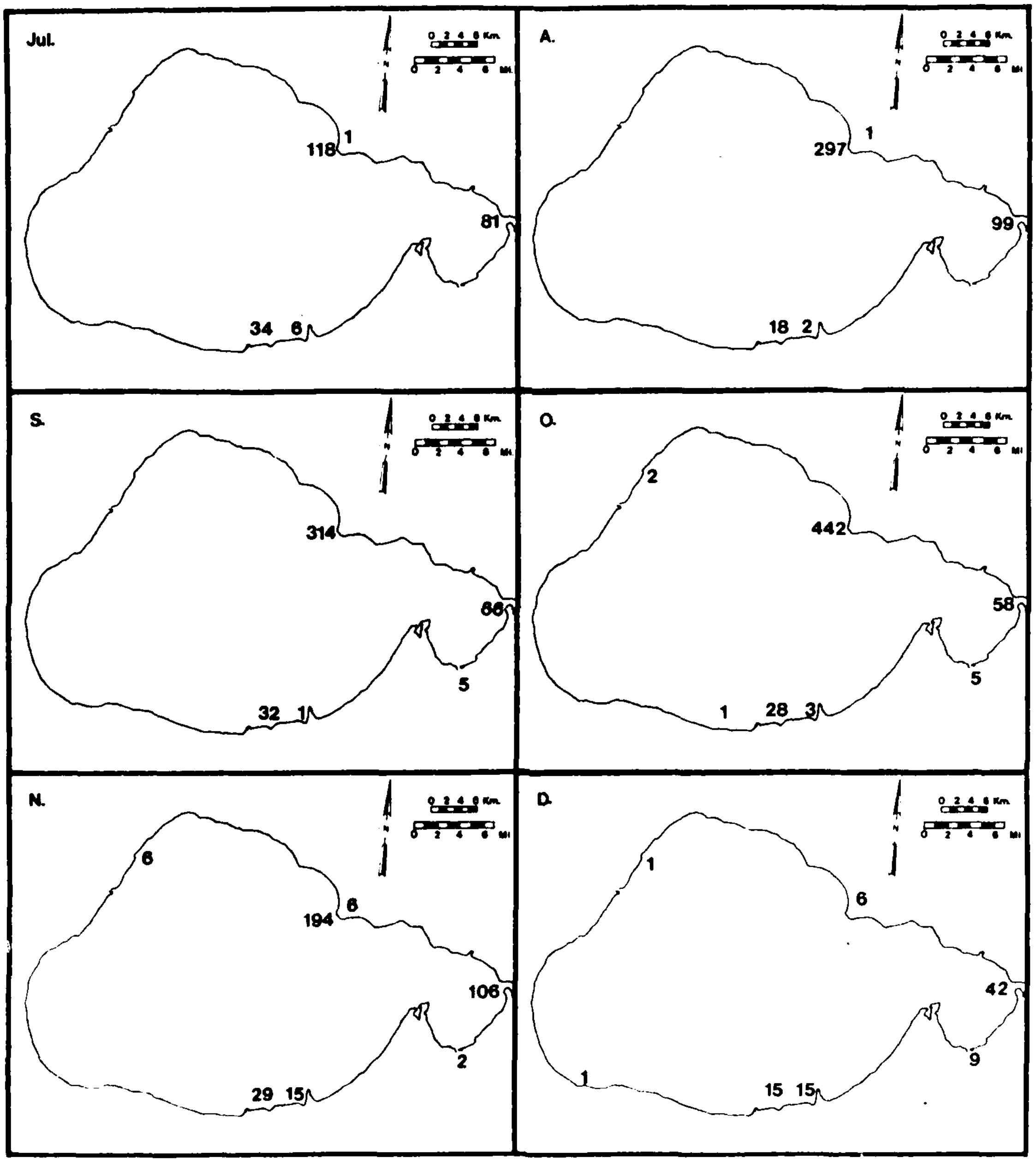

Figure 23B. Monthly distribution (July-Dec) of Syngnathus scovelli in Lake Pontchartrain, LA, in 1978.

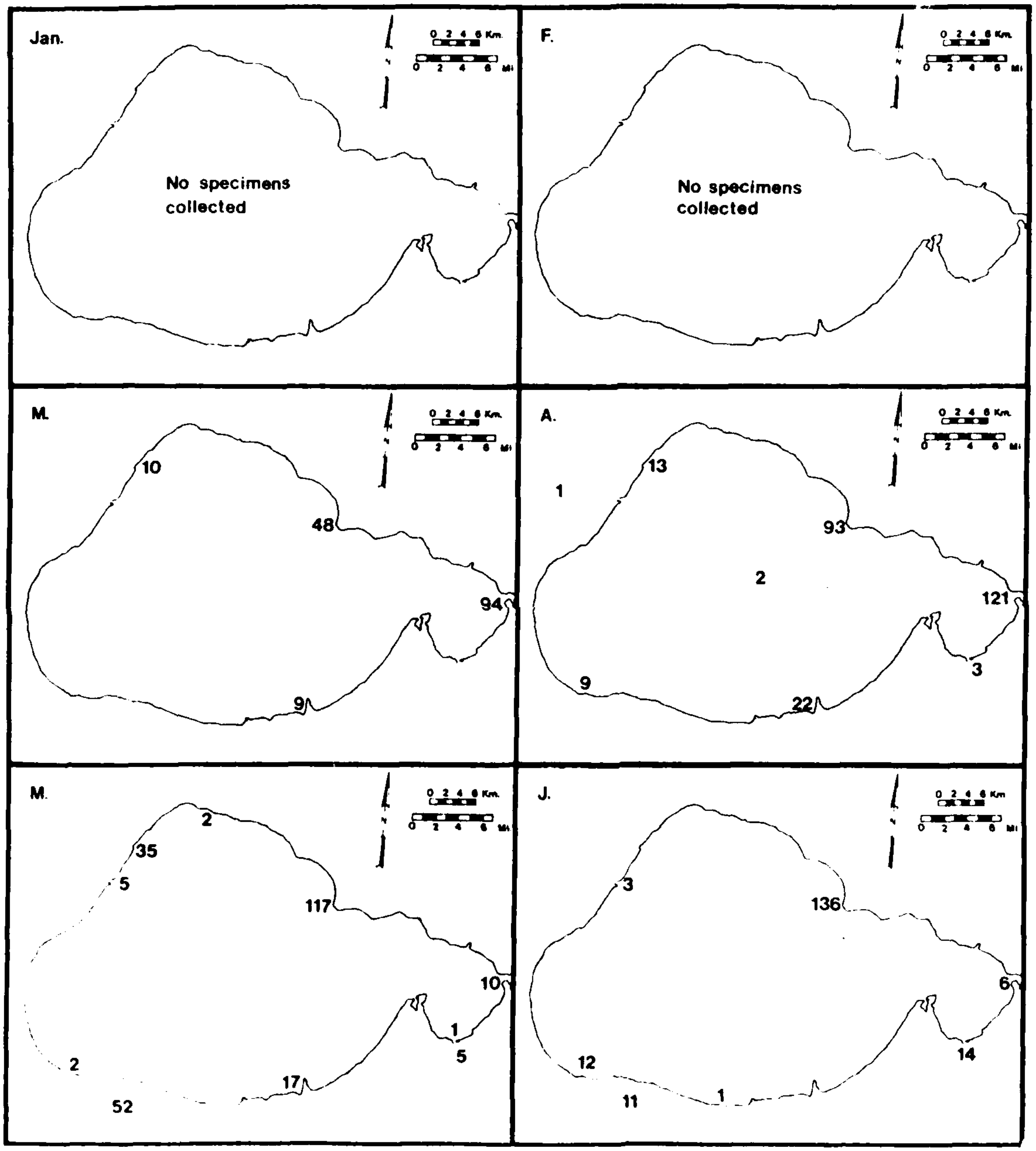

Figure 24A. Monthly distribution (Jan-June) of Leiostomus xanthurus in Lake Pontchartrain, LA, in 1978.

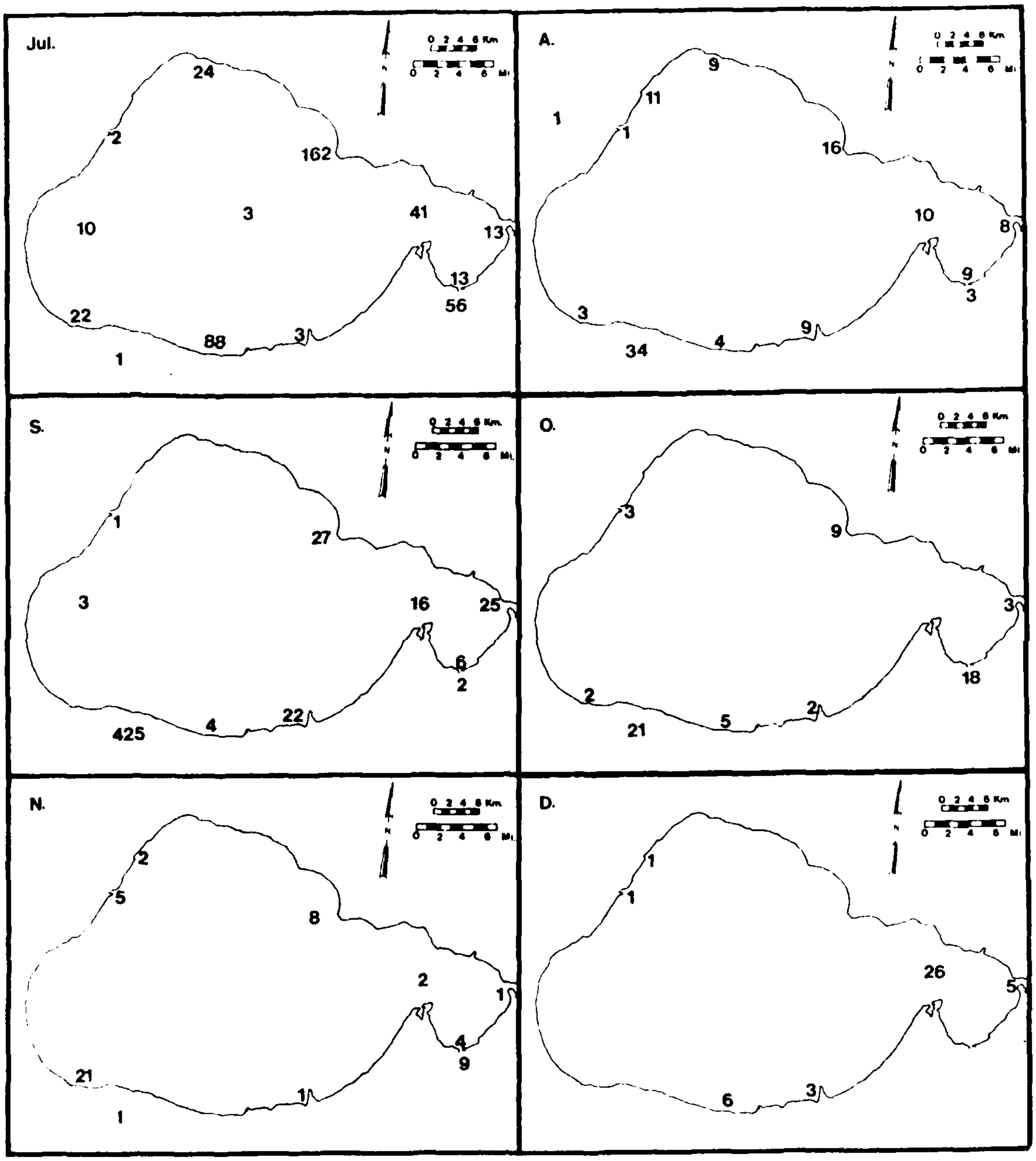

Figure 24B. Monthly distribution (July-Dec) of Leiostomus xanthurus in Lake Pontchartrain, LA, in 1978.

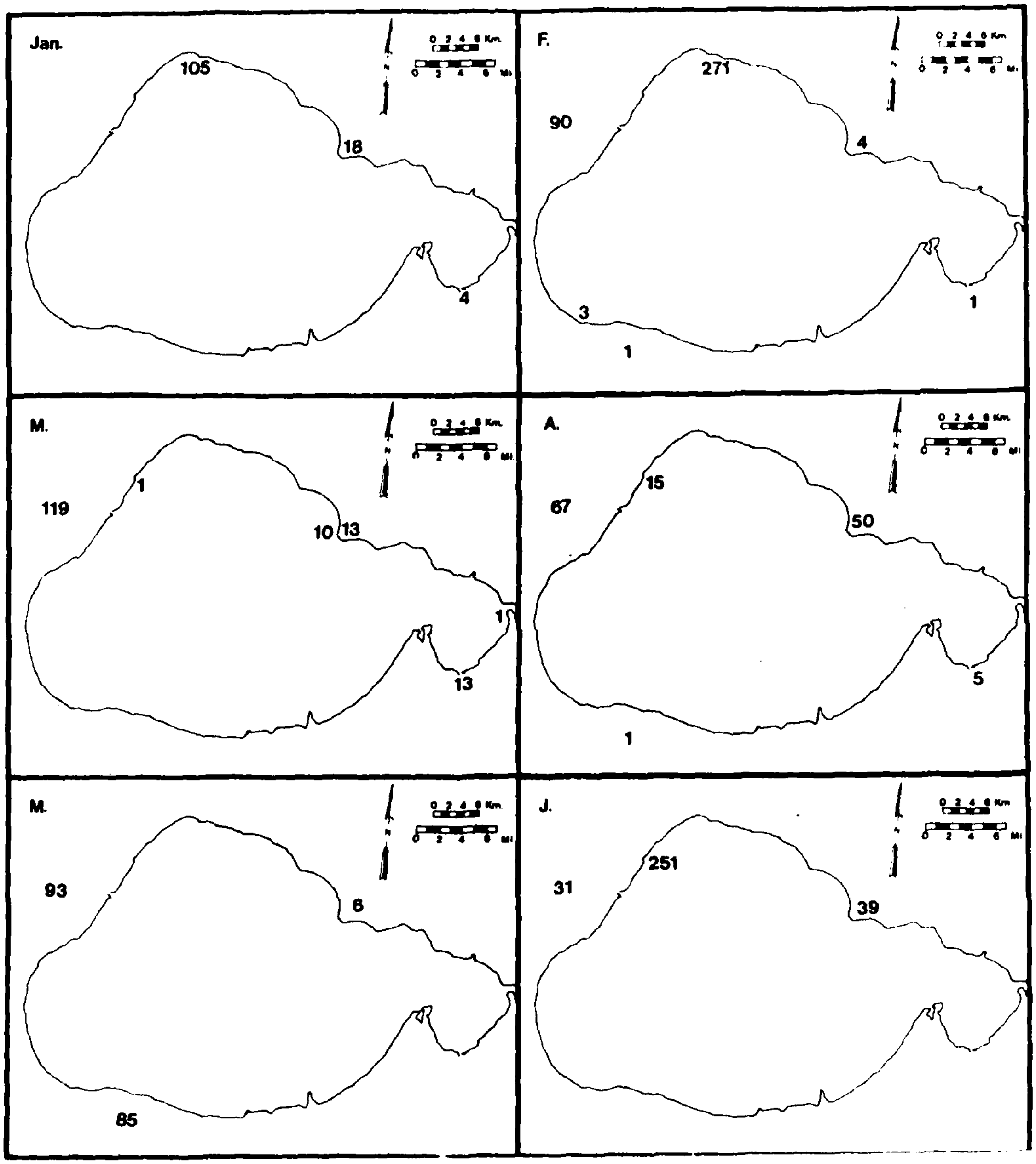

Figure 25A. Monthly distribution (Jan-June) of Gambusia affinis in Lake Pontchartrain, LA, in 1978.

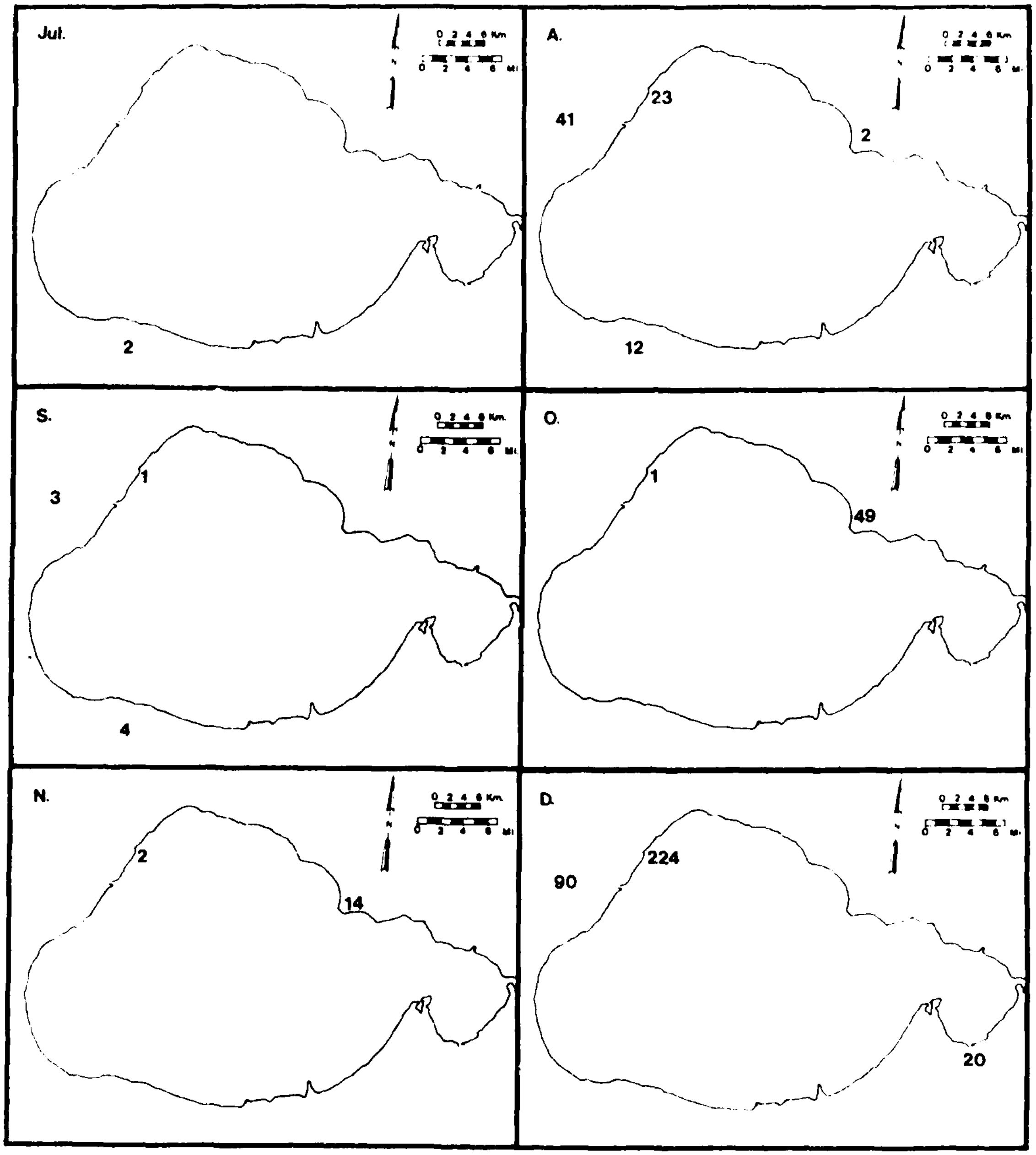

Figure 25B. Monthly distribution (July-Dec) of Gambusia affinis in Lake Pontchartrain, LA, in 1978.

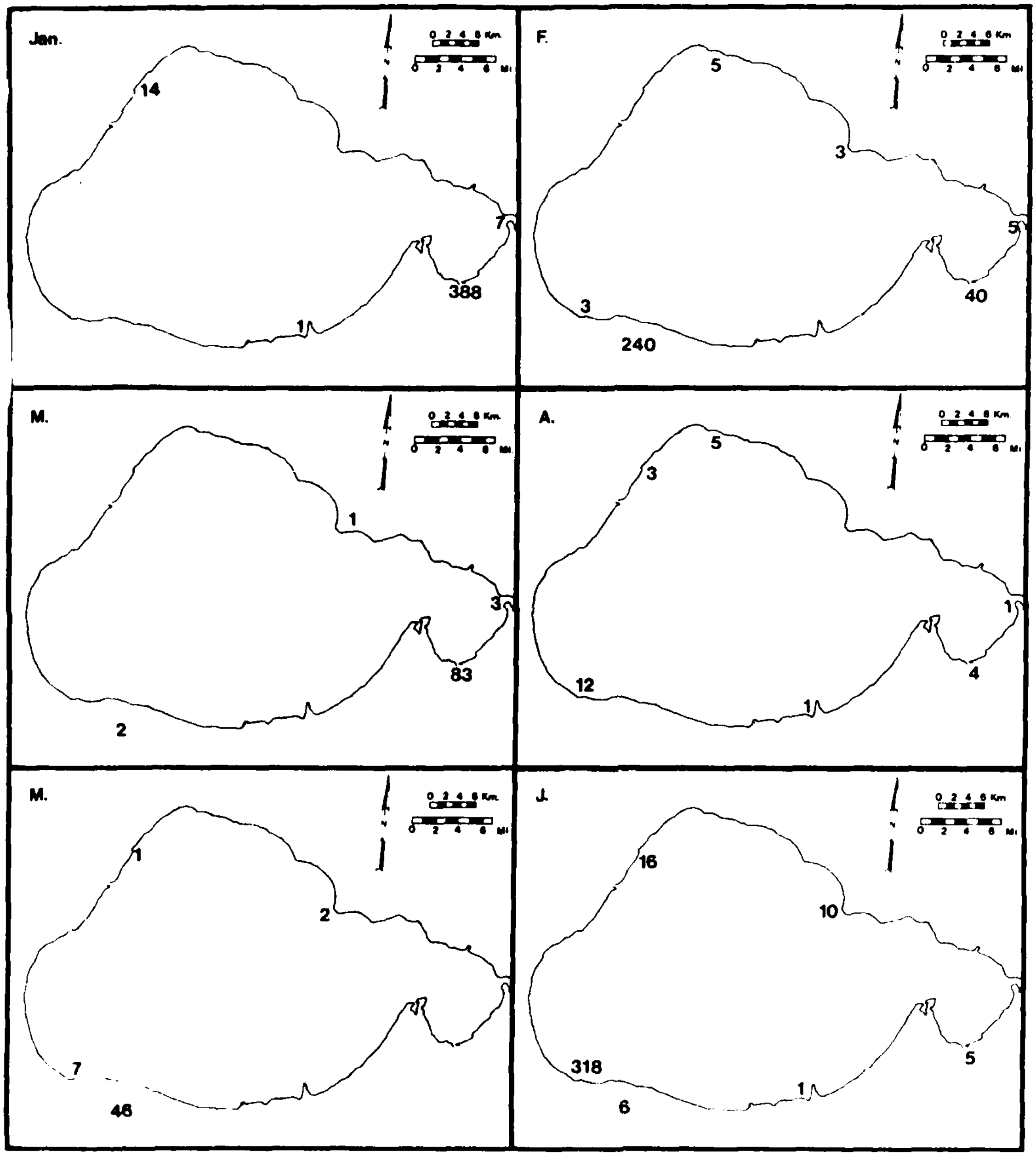

Figure 26A. Monthly distribution (Jan-June) of Fundulus grandis in Lake Pontchartrain, LA, in 1978.

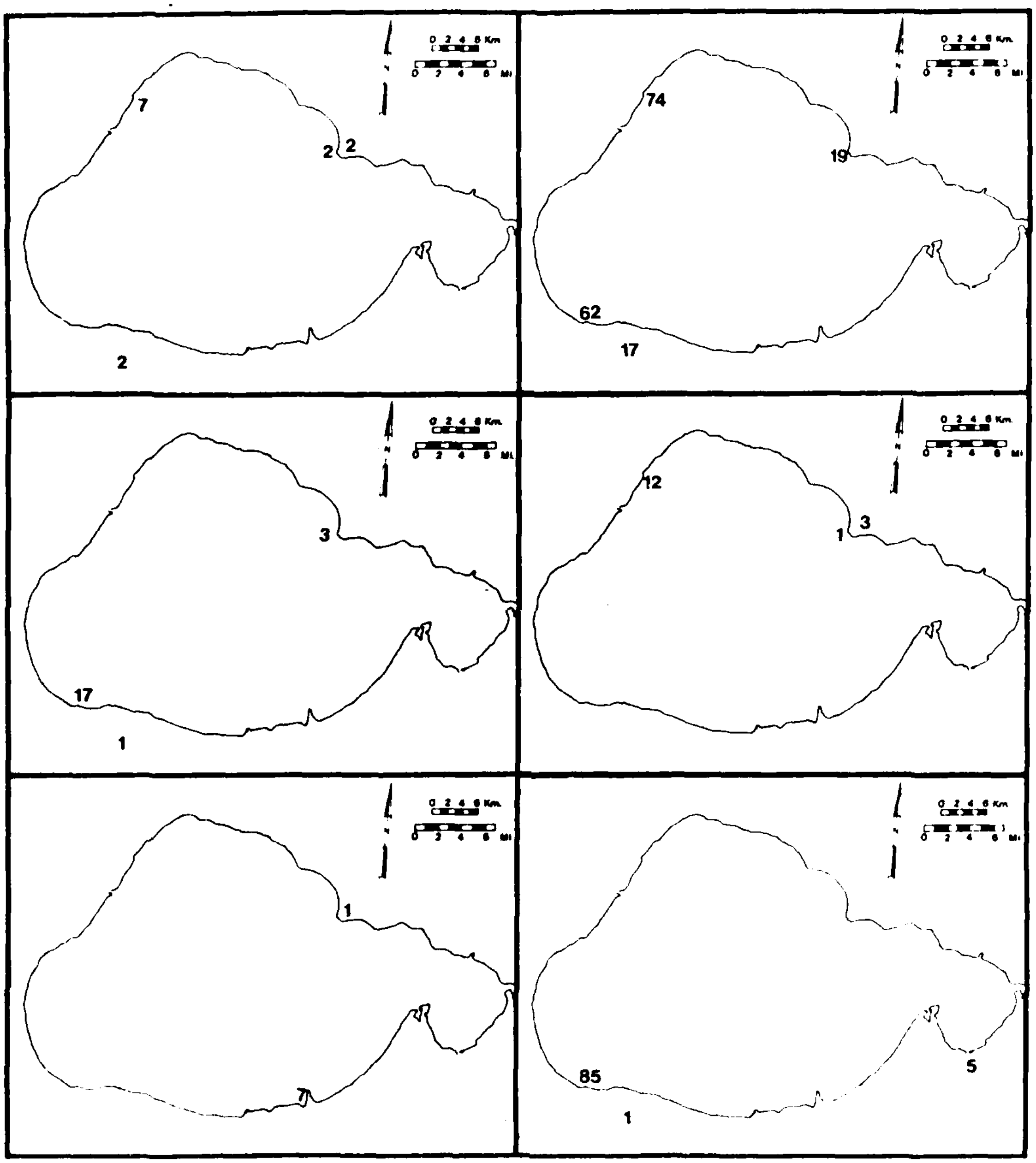

Figure 26B. Monthly distribution (July-Dec) of Fundulus grandis in Lake Pontchartrain, LA, in 1978.

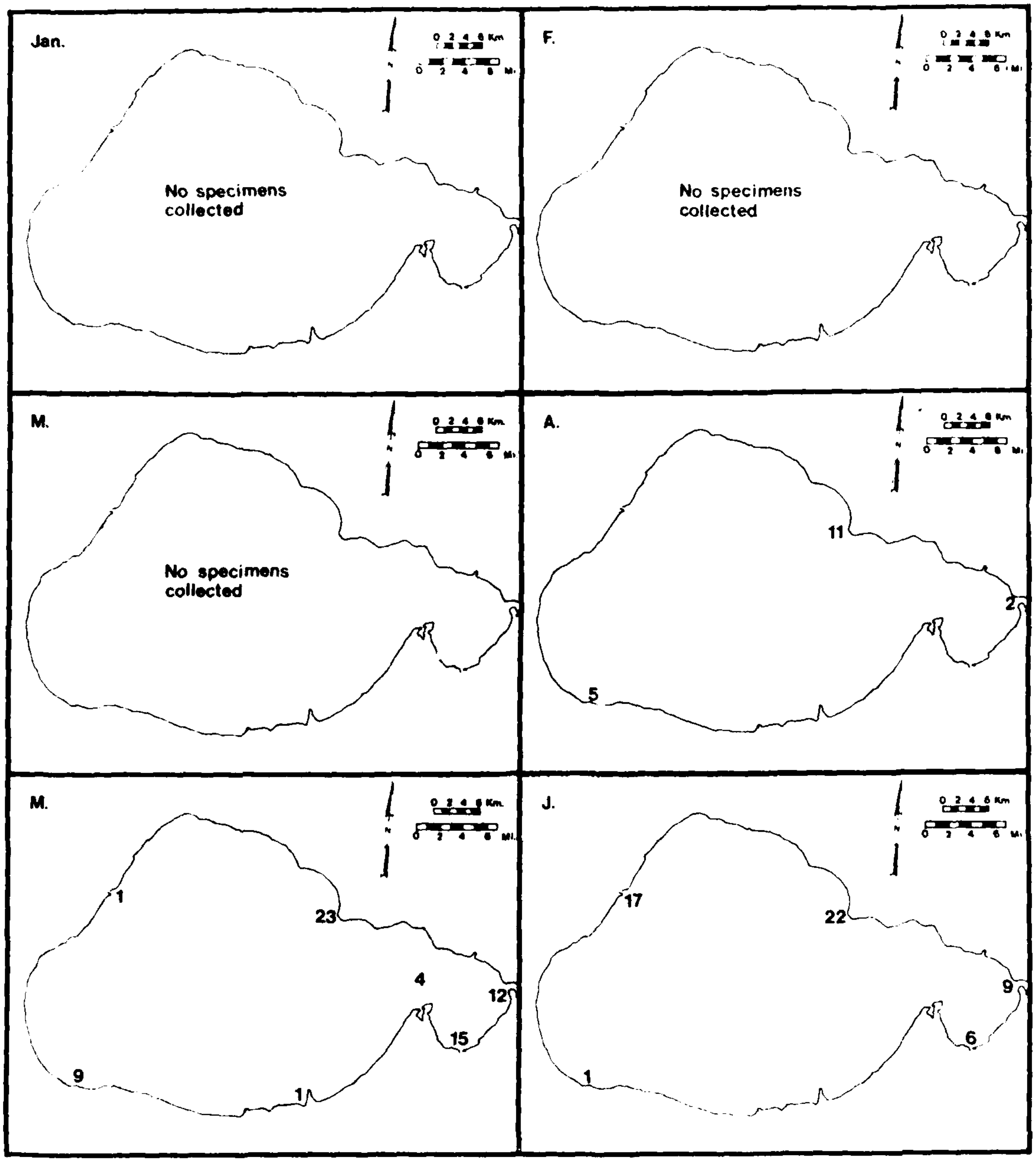

Figure 27A. Monthly distribution (Jan-June) of Arius felis in Lake Pontchartrain, LA, in 1978.

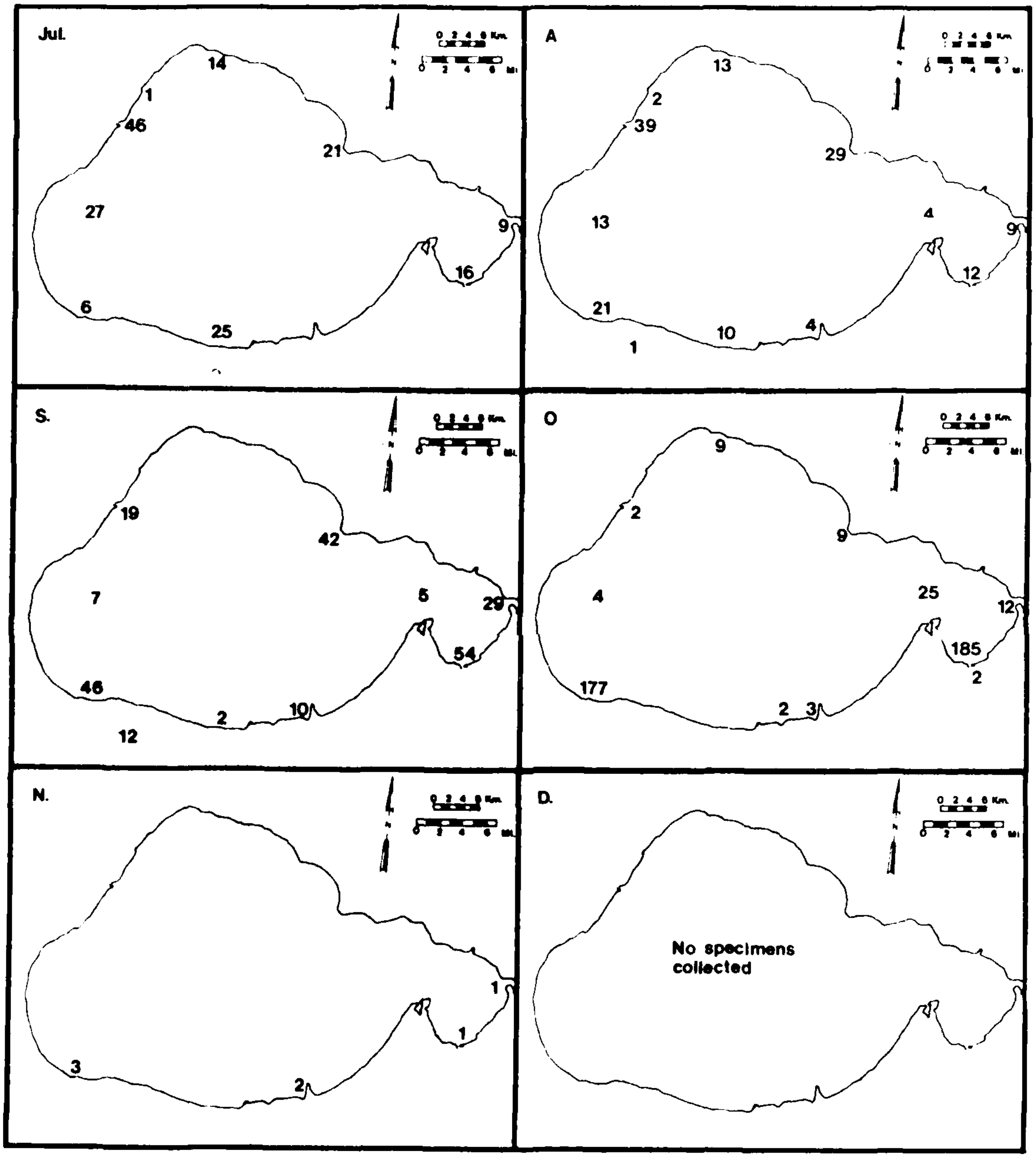

Figure 27B. Monthly distribution (July-Dec) of Arius felis in Lake Pontchartrain, LA, in 1978.

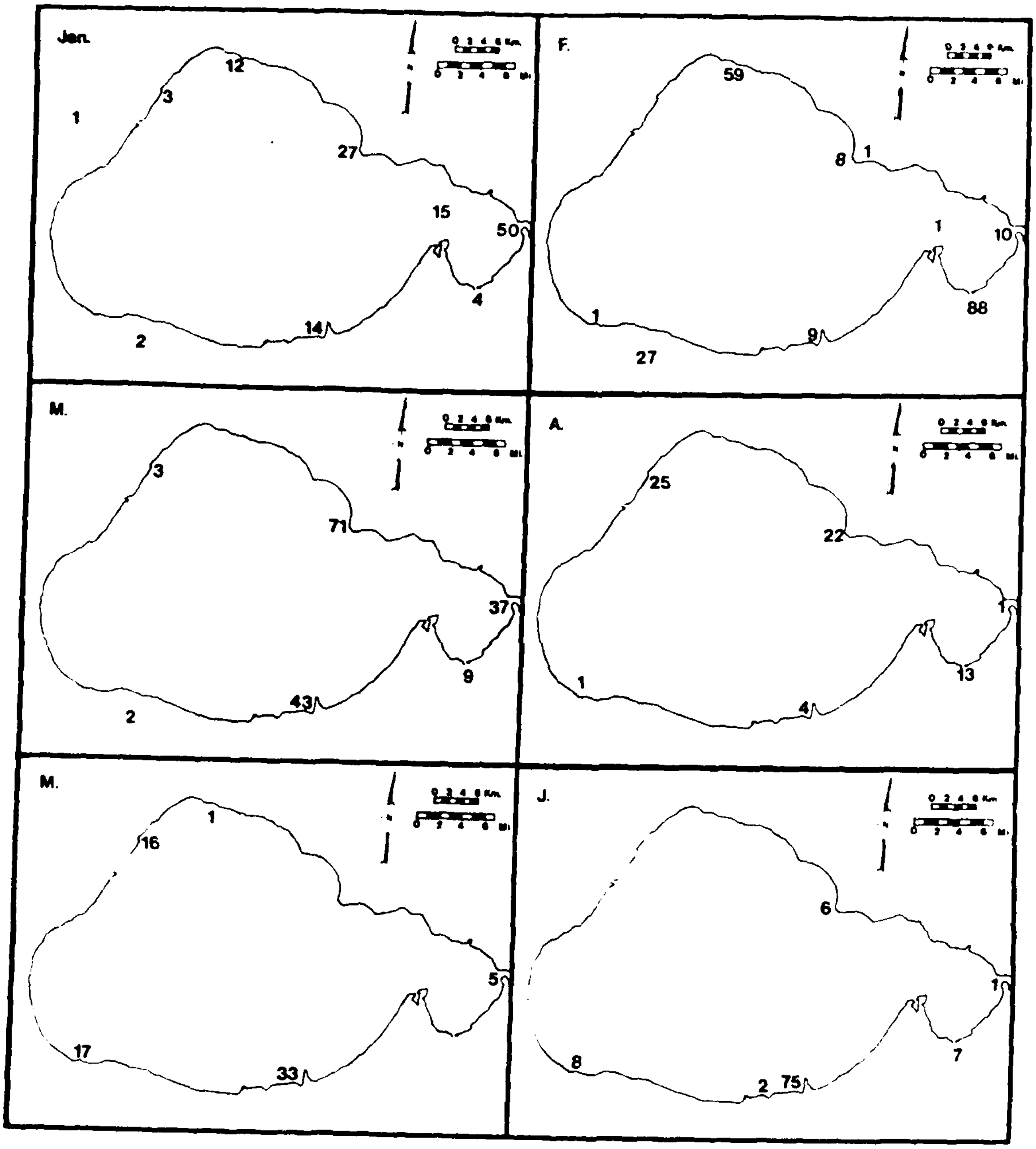

Figure 28A. Monthly distribution (Jan-June) of Mugil cephalus in Lake Pontchartrain, LA, in 1978.

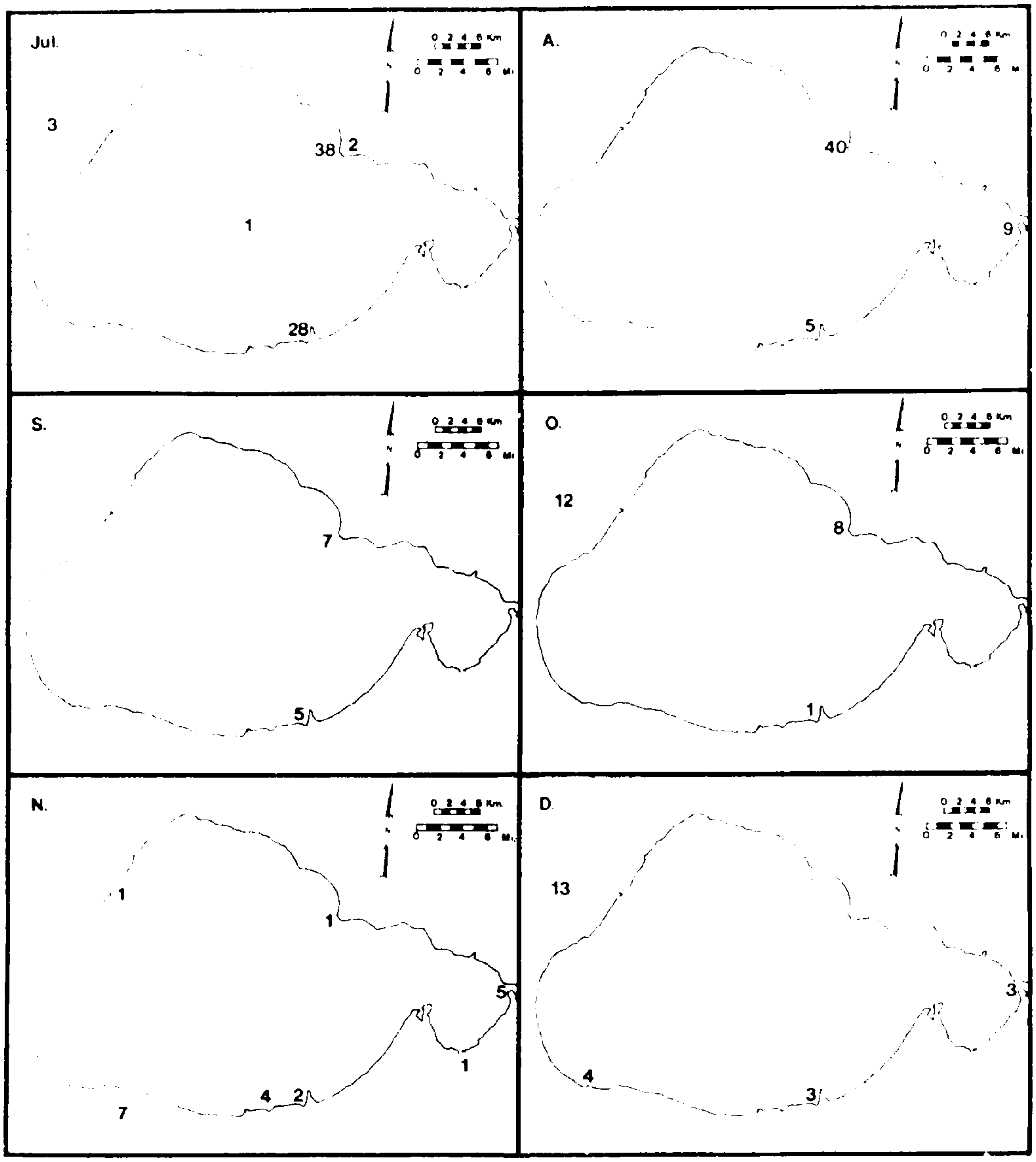

Figure 28B. Monthly distribution (July-Dec) of Mugil cephalus in Lake Pontchartrain, LA, in 1978.

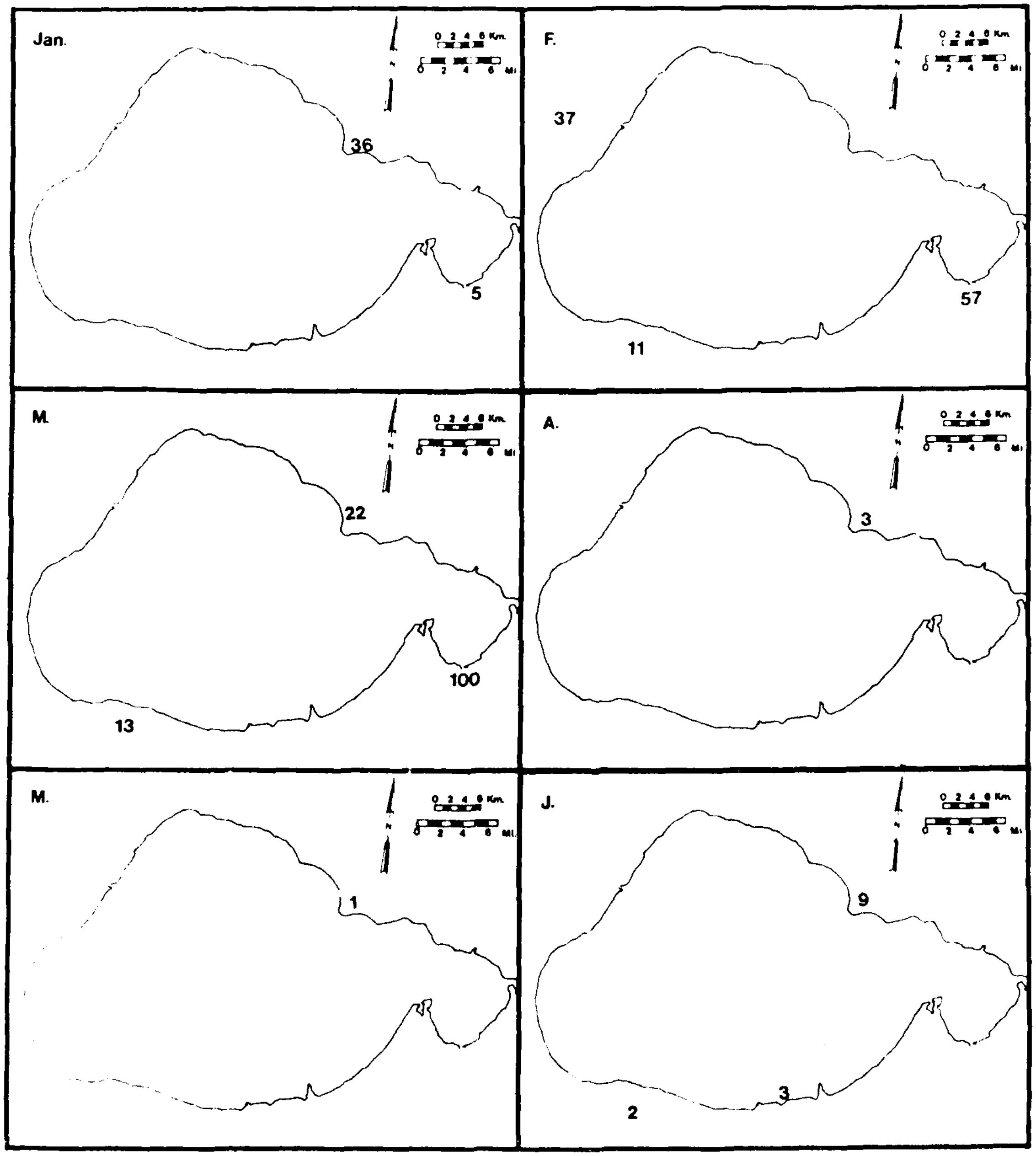

Figure 29A. Monthly distribution (Jan-June) of Lepomis punctatus in Lake Pontchartrain, LA, in 1978.

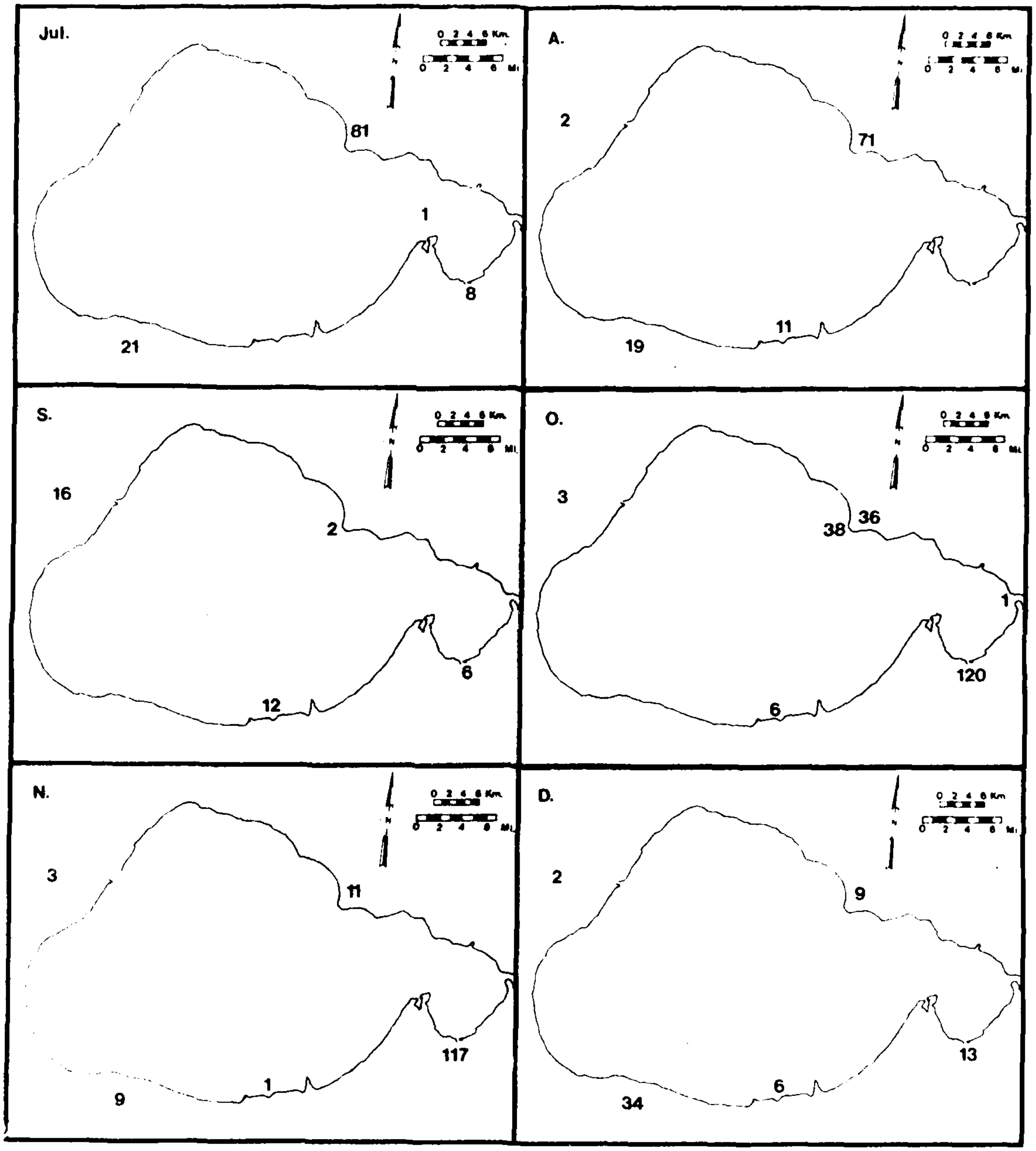

Figure 29B. Monthly distribution (July-Dec) of Lepomis punctatus in Lake Pontchartrain, LA, in 1978.

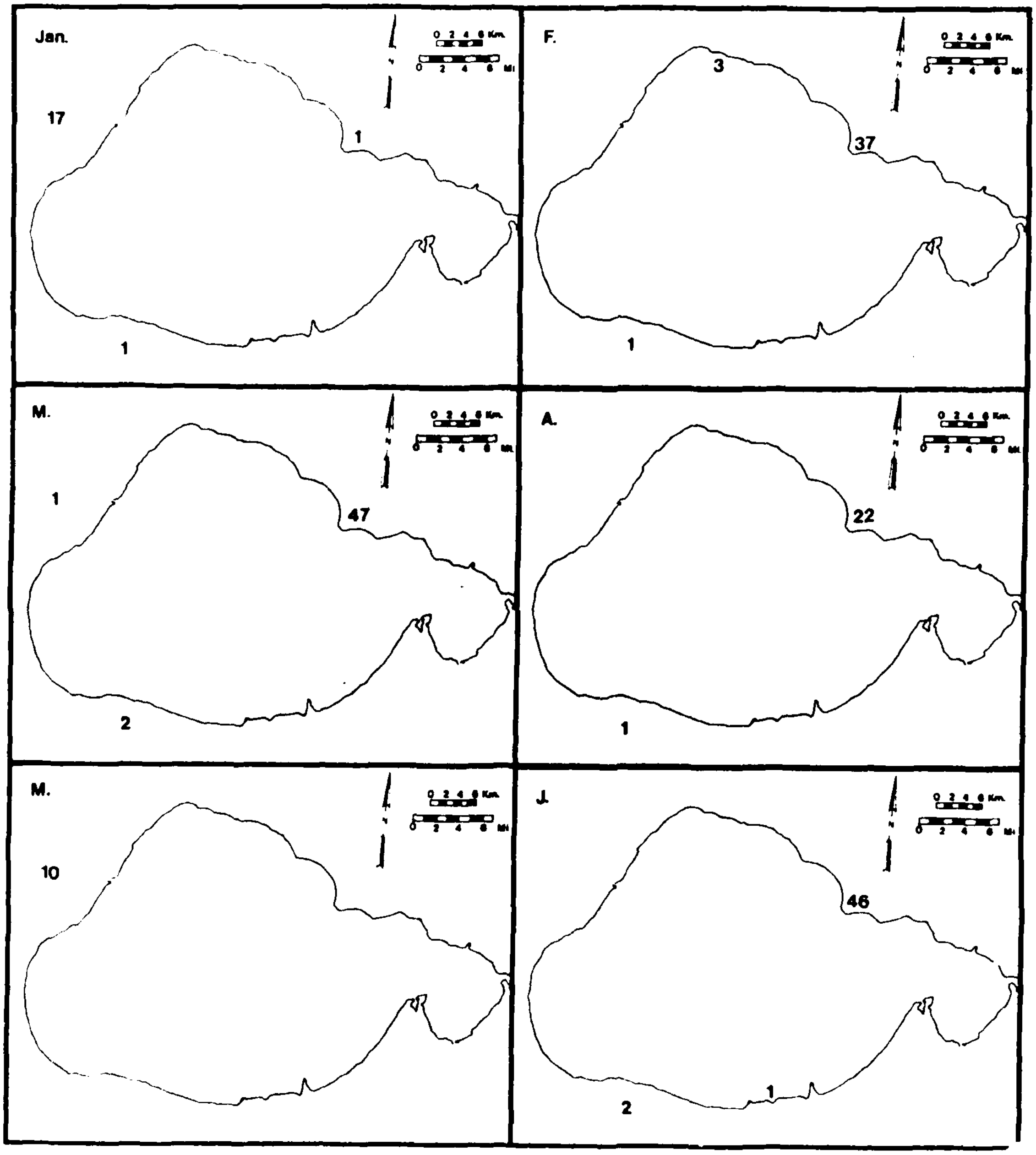

Figure 30A. Monthly distribution (Jan-June) of Lepomis macrochirus in Lake Pontchartrain, LA, in 1978.

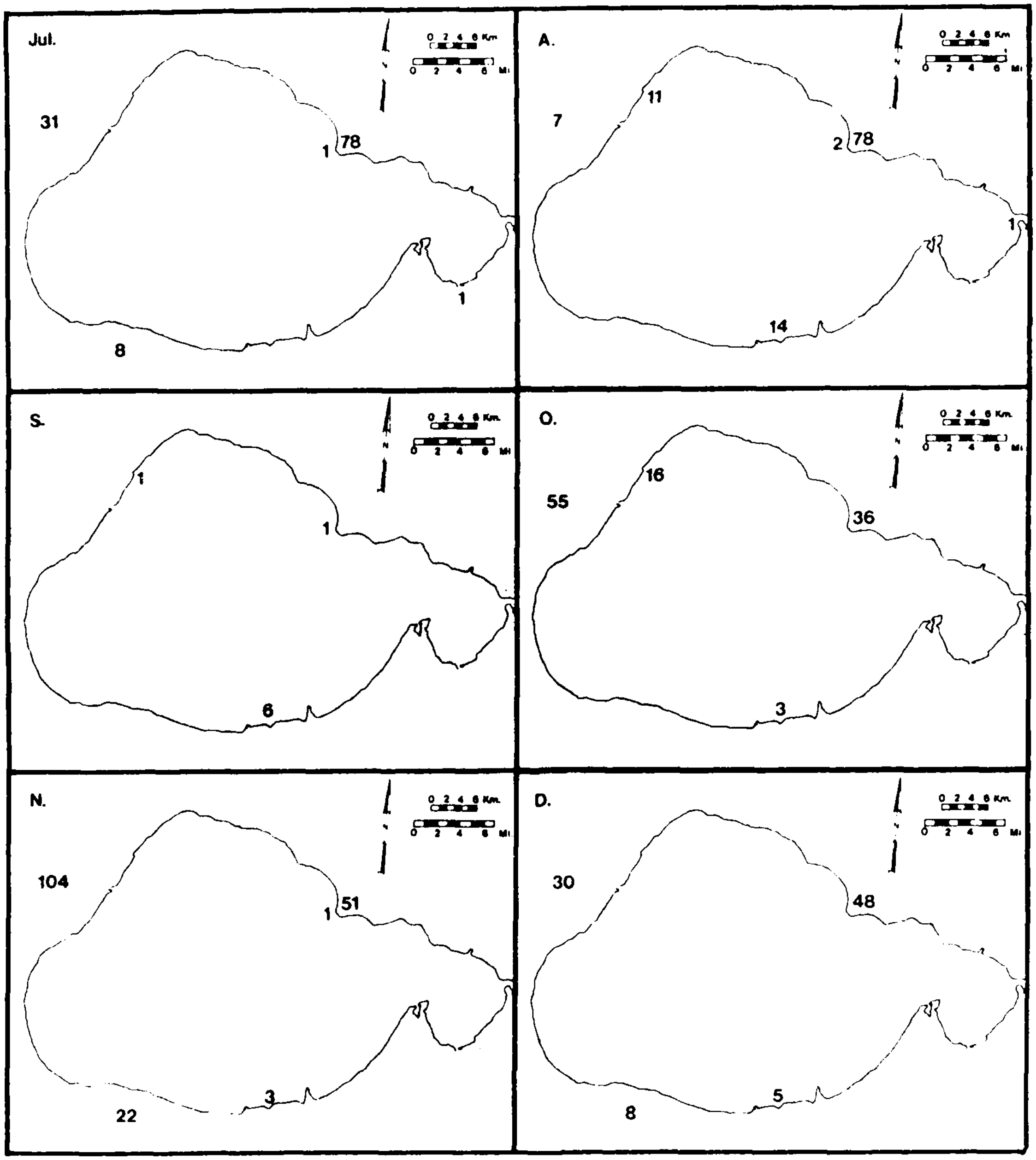

Figure 30B. Monthly distribution (July-Dec) of Lepomis macrochirus in Lake Pontchartrain, LA, in 1978.

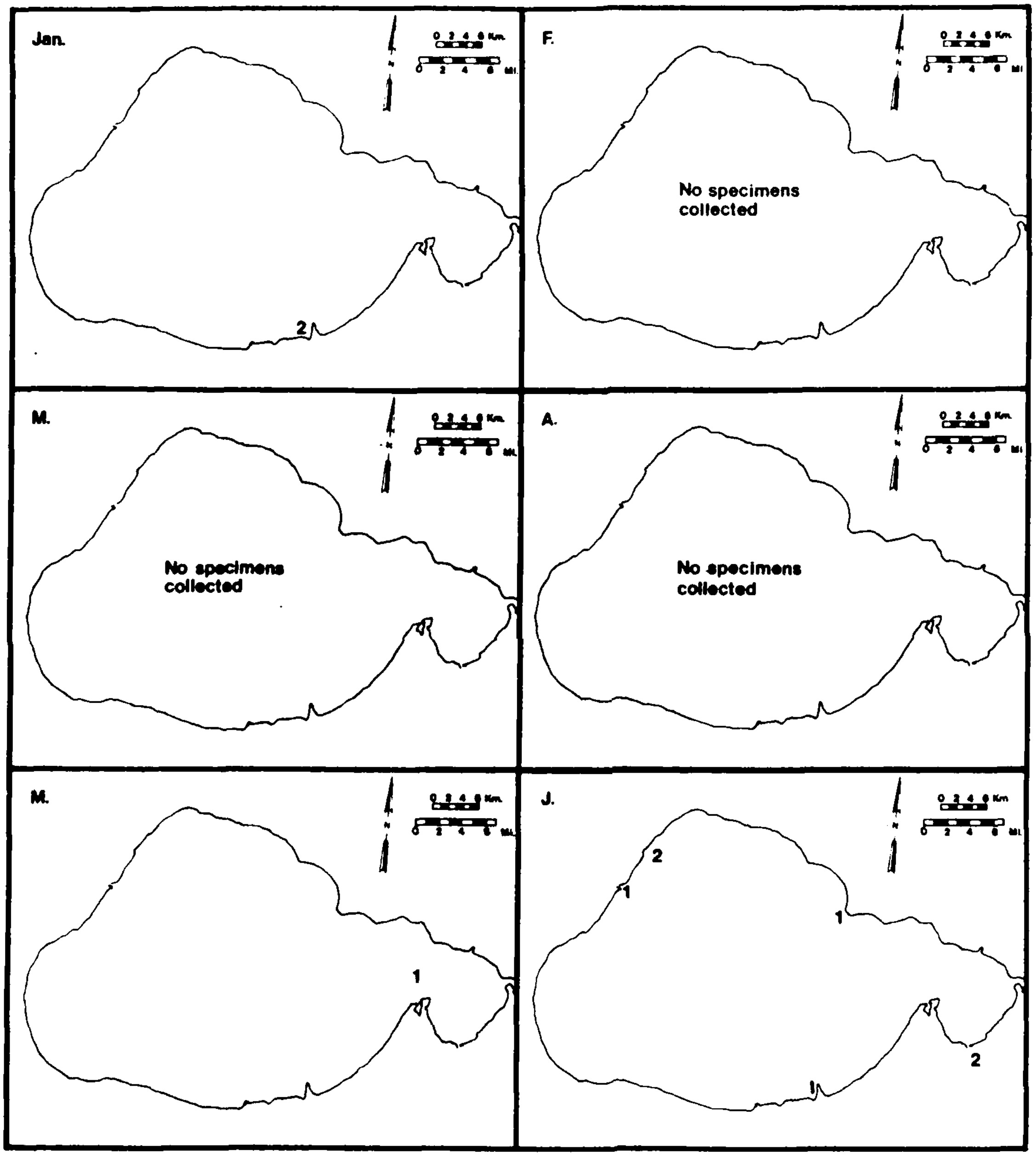

Figure 31A. Monthly distribution (Jan-June) of <u>Cynoscion arenarius</u> in Lake Pontchartrain, LA, in 1978.

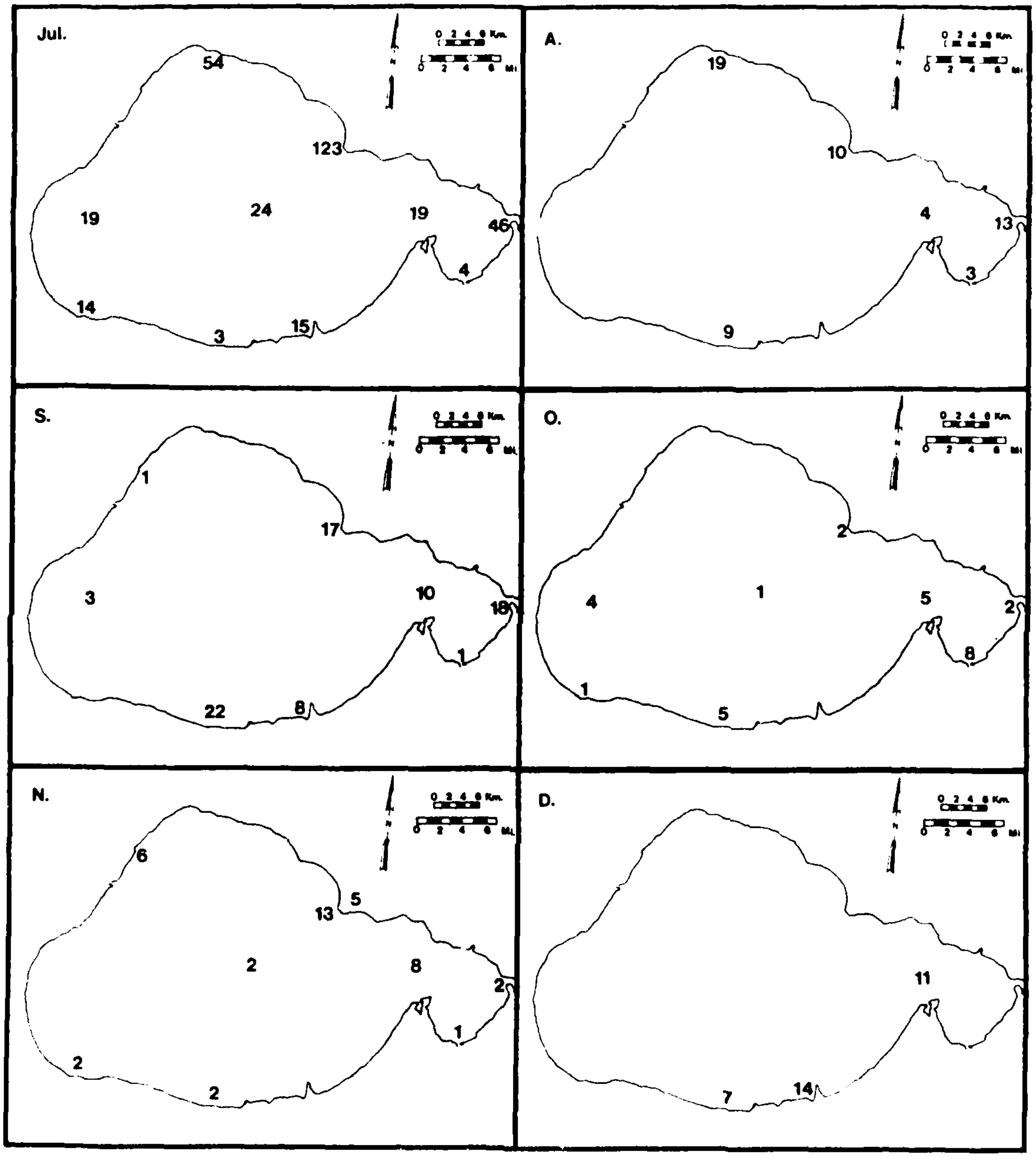

Figure 31B. Monthly distribution (July-Dec) of Cynoscion arenarius in Lake Pontchartraion, LA, in 1978.

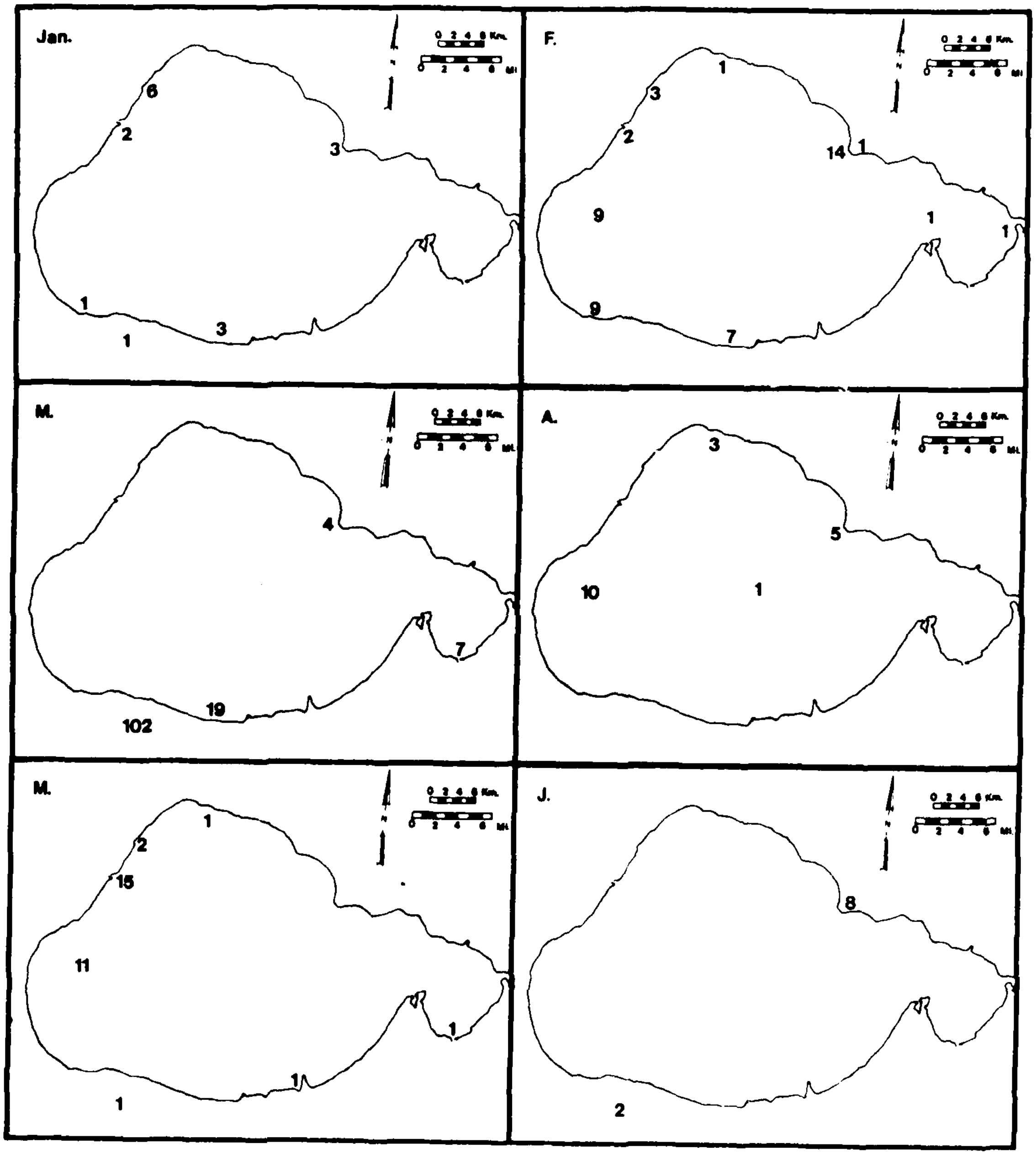

Figure 32A. Monthly distribution (Jan-June) of Ictalurus furcatus in Lake Pontchartrain, LA, in 1978.

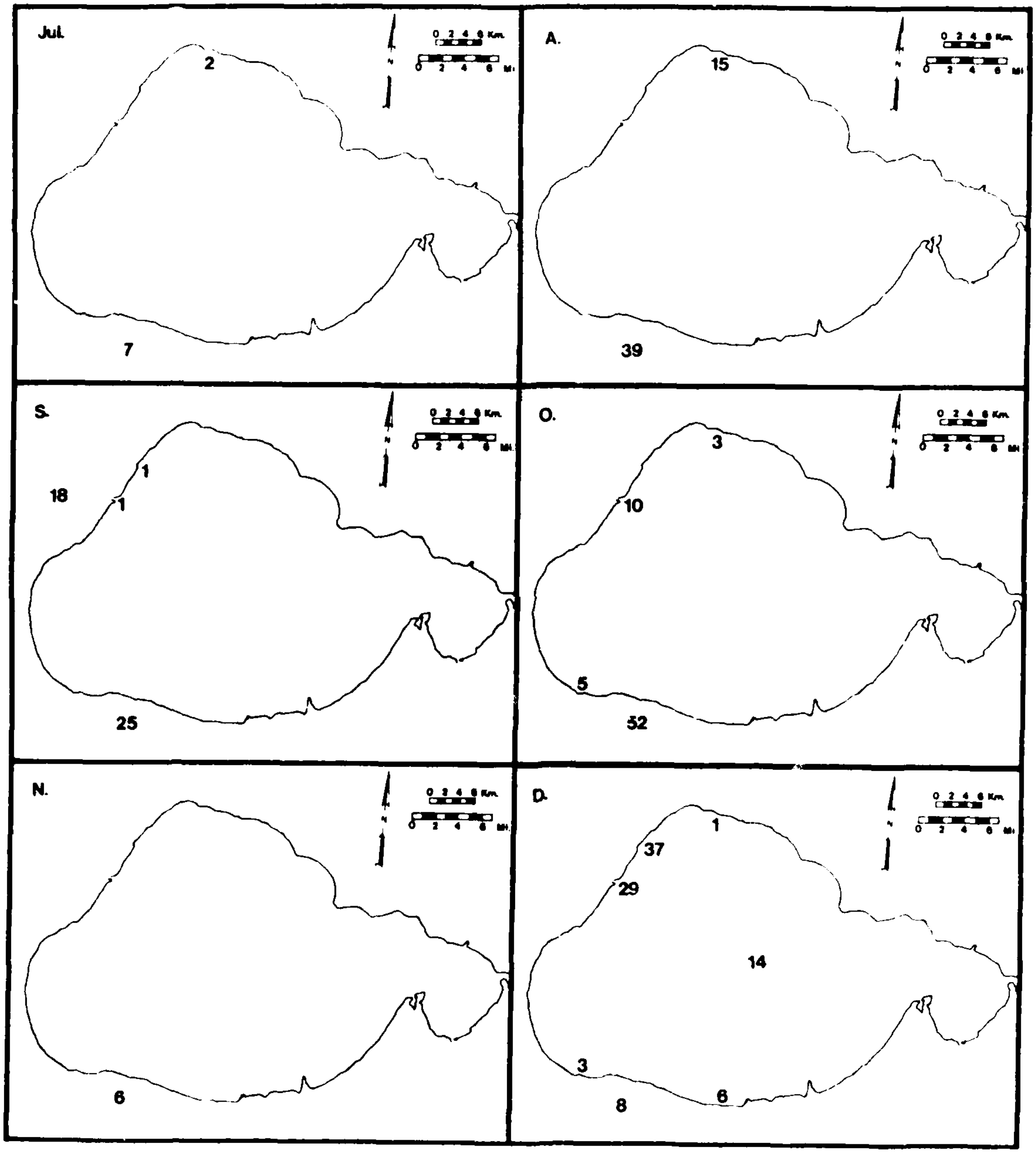

Figure 32B. Monthly distribution (July-Dec) of Ictalurus furcatus in Lake Pontchartrain, LA, in 1978.

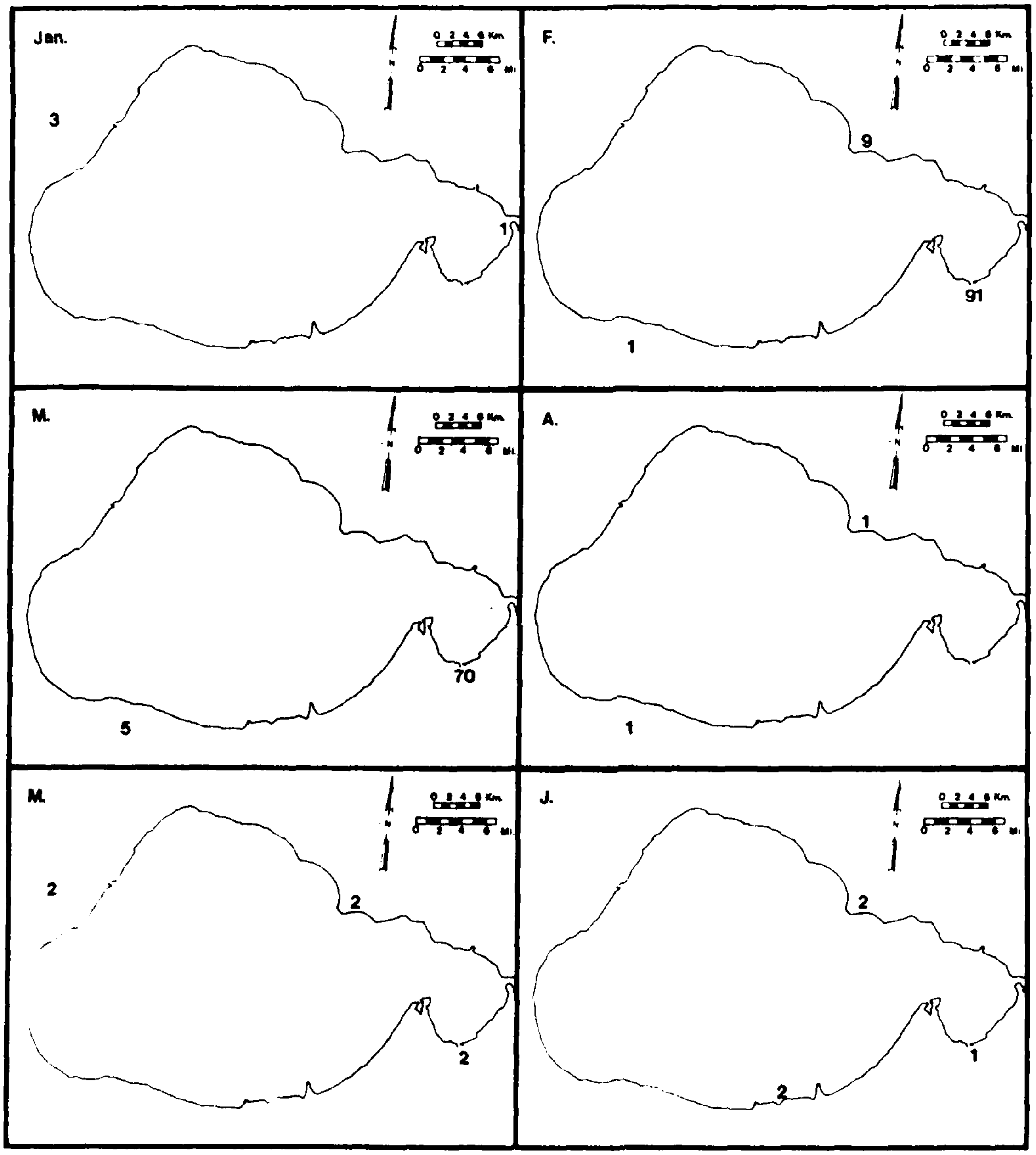

Figure 33A. Monthly distribution (Jan-June) of Lepomis microlophus in Lake Pontchartrain, LA, in 1978.

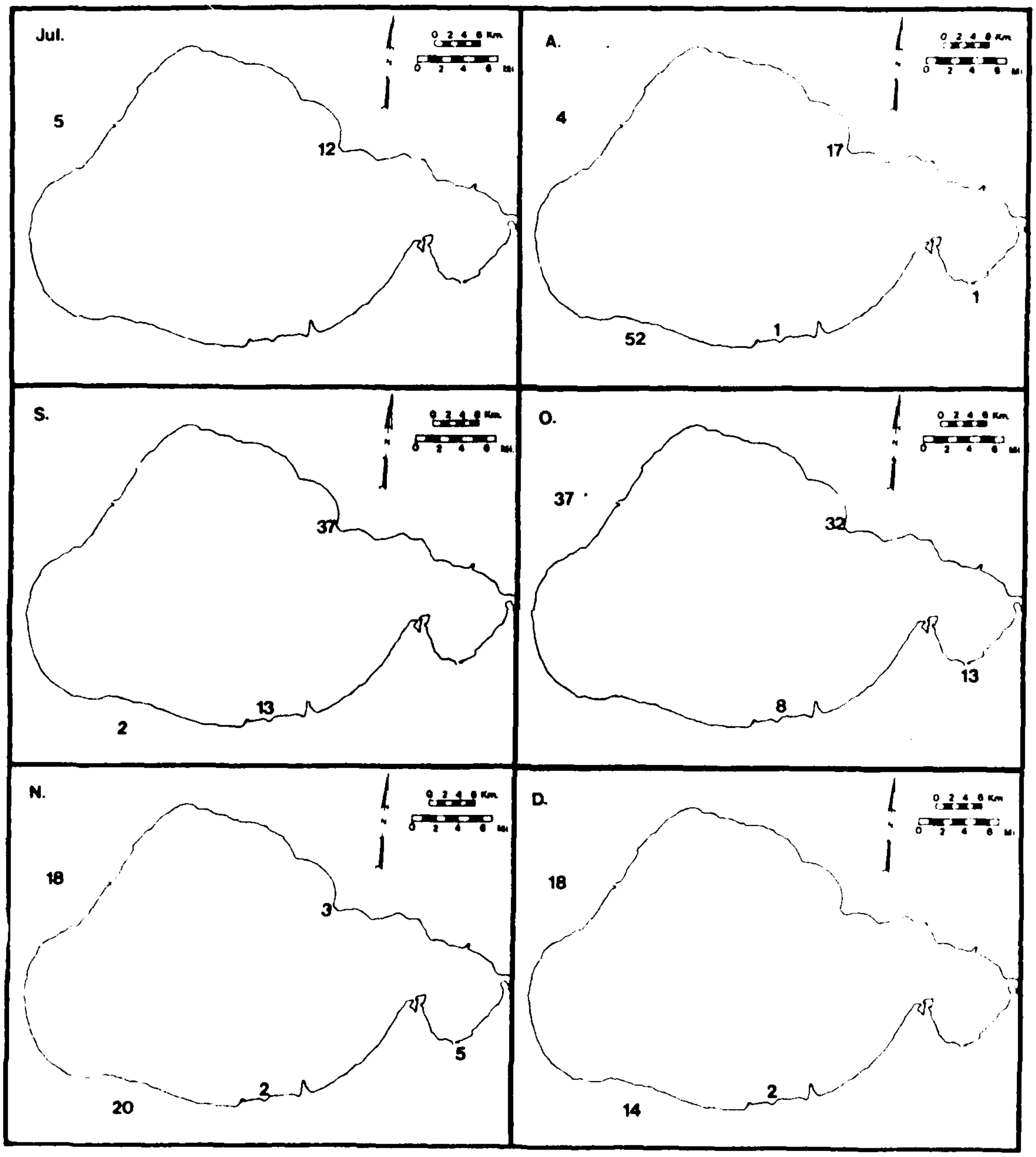

Figure 33B. Monthly distribution (July-Dec) of Lepomis microlophus in Lake Pontchartrain, LA, in 1978.

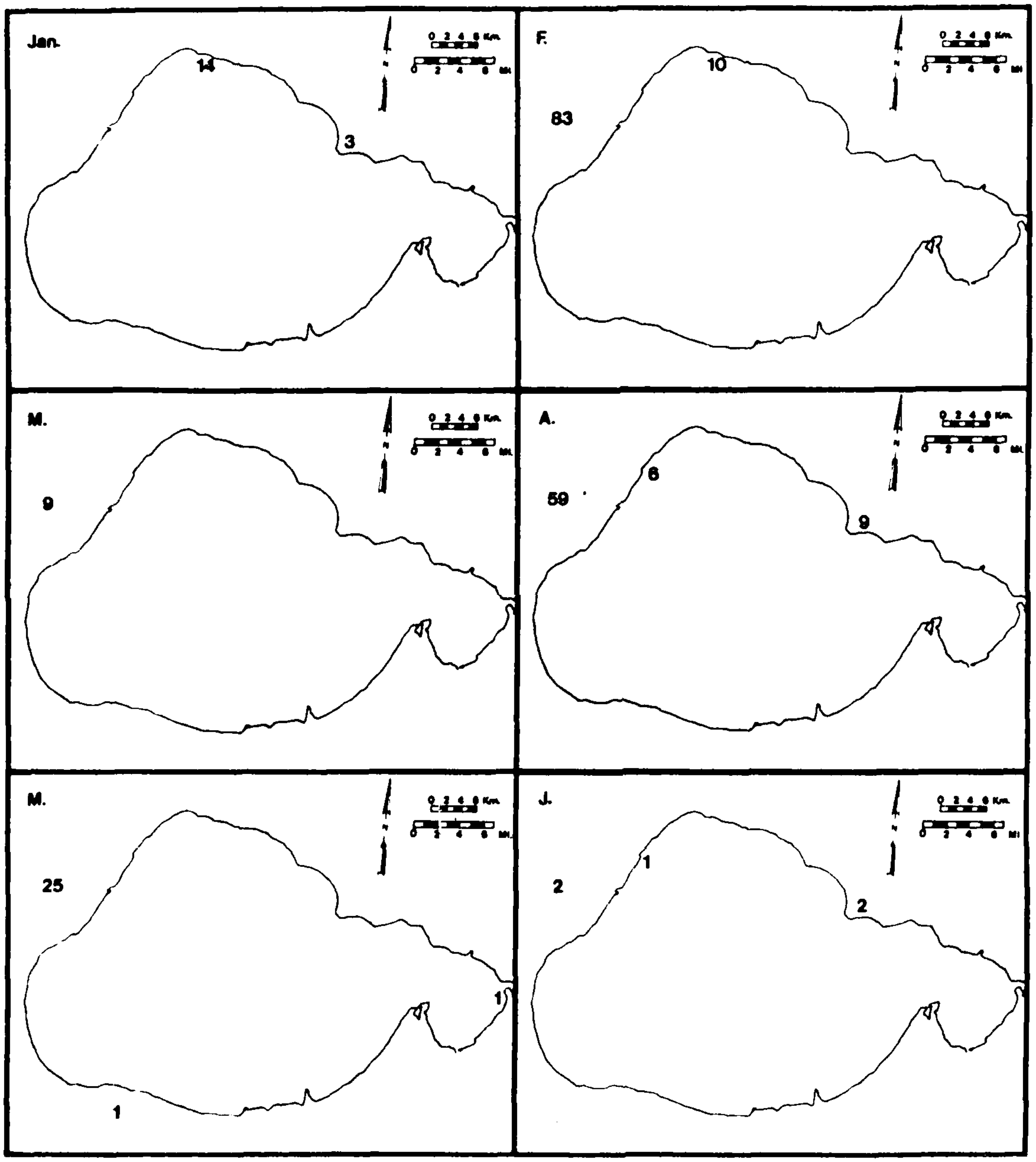

Figure 34A. Monthly distribution (Jan-June) of Heterandria formosa in Lake Pontchartrain, LA,in 1978.

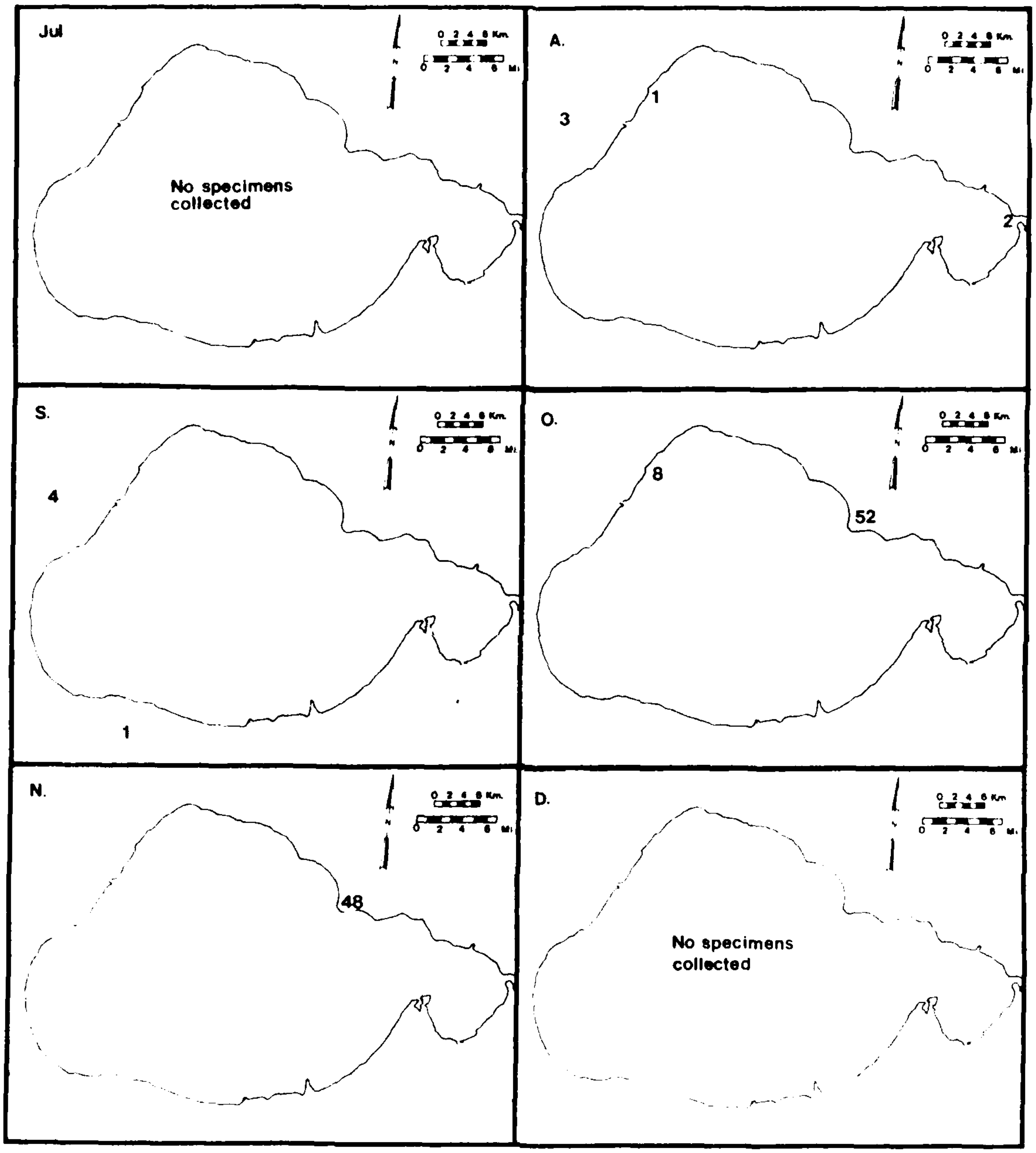

Figure 34B. Monthly distribution (July-Dec) of Heterandria formosa in Lake Pontchartrain, LA, in 1978.

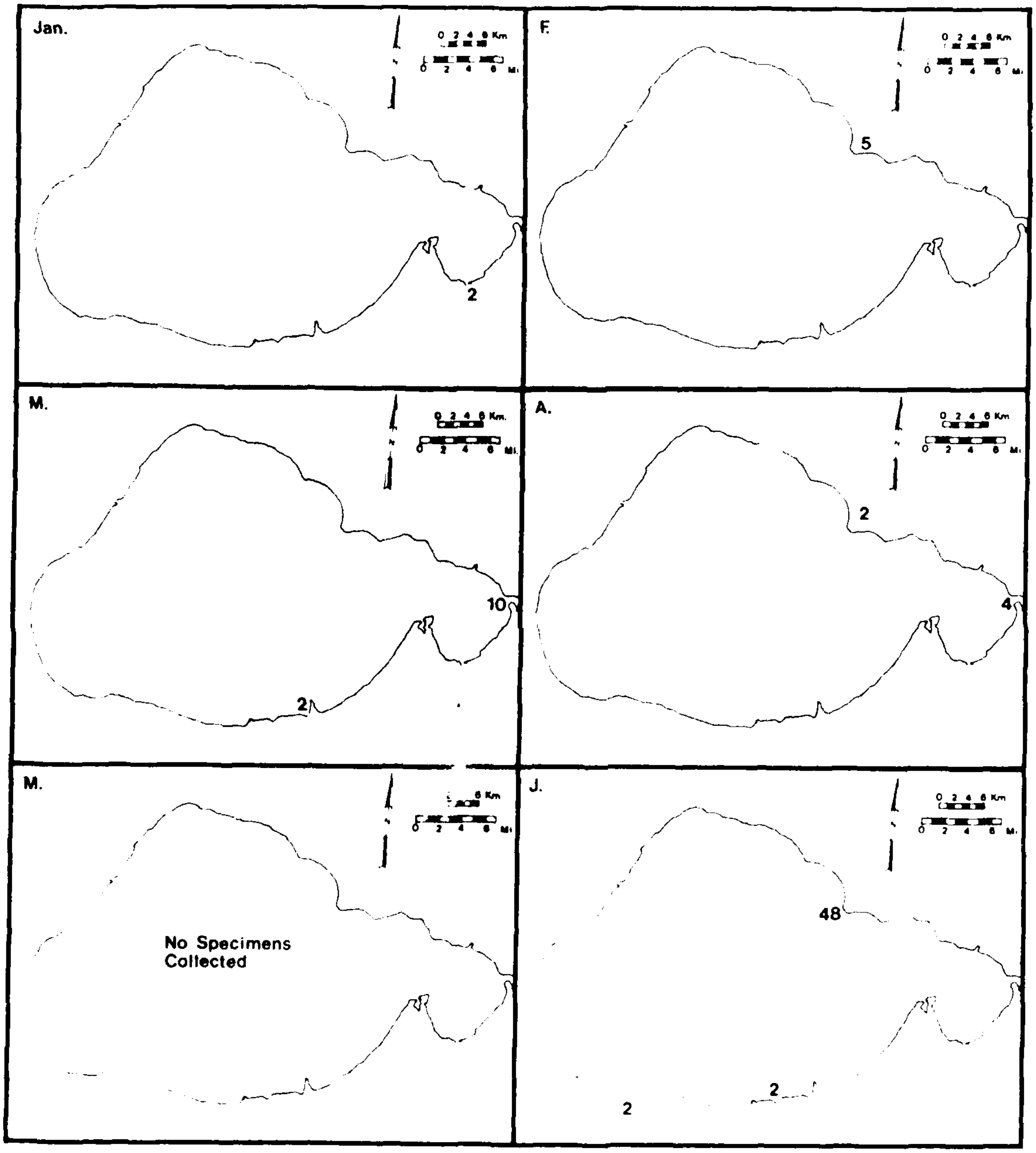

Figure 35A. Monthly distribution (Jan-June) of Gobiosoma bosci in Lake Pontchartrain, LA, in 1978.

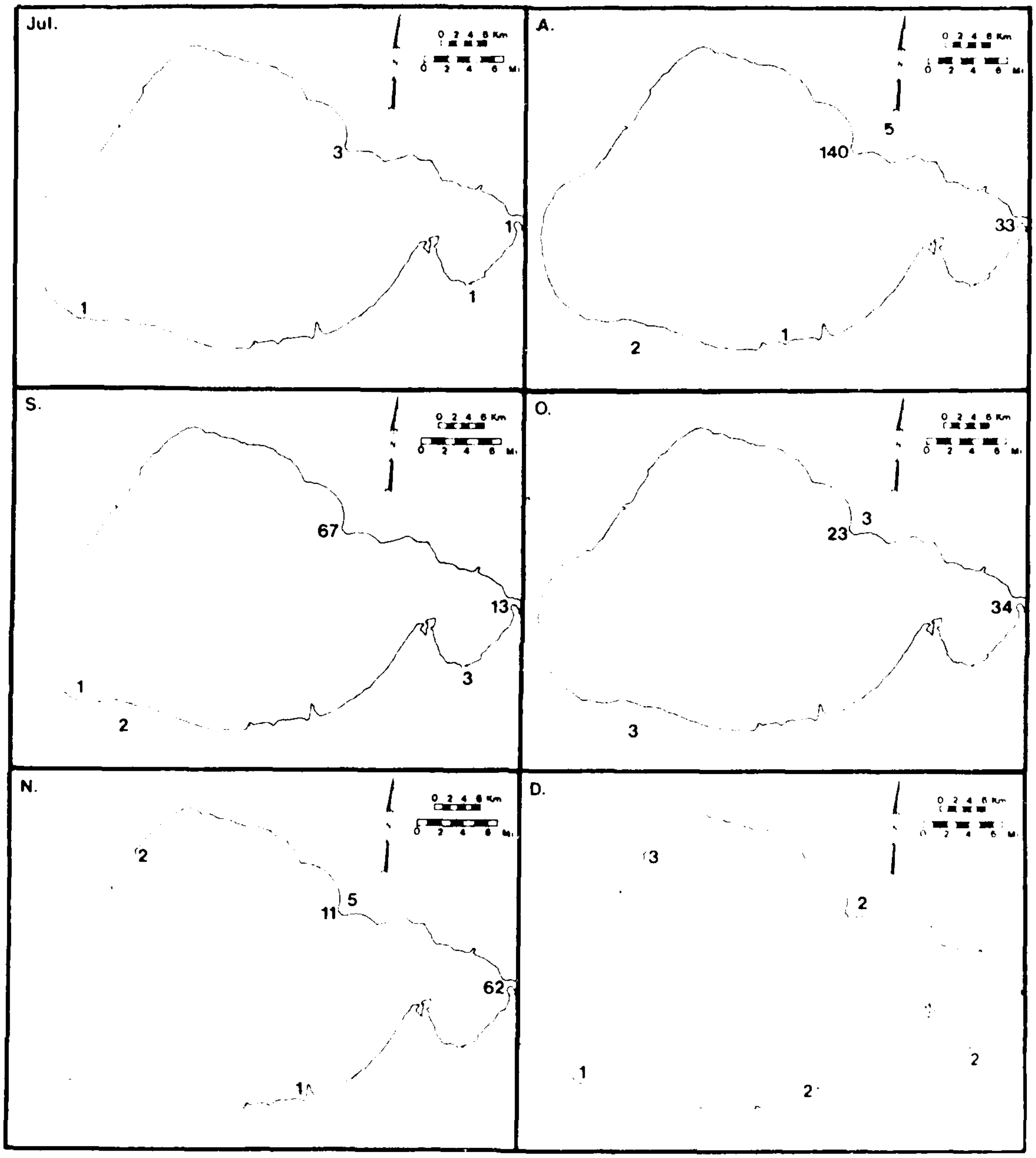

Figure 35B. Monthly distribution (July-Dec) of Gobioso[illegible]
Lake Pontchartrain, LA, in 1978.

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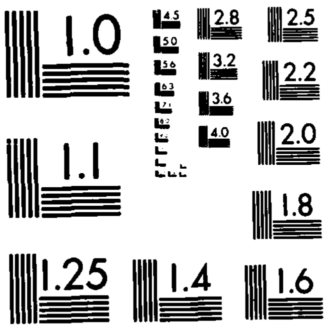

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Chapter 13

ASPECTS OF THE LIFE HISTORY OF ANCHOA MITCHILLI CUVIER AND VALENCIENNES IN LAKE PONTCHARTRAIN, LOUISIANA JANUARY THROUGH DECEMBER 1978

by

J. Stephen Verret

ABSTRACT

A study of aspects of the life history of *Anchoa mitchilli* Cuvier and Valenciennes in Lake Pontchartrain, Louisiana, was conducted in conjunction with a study of the nekton community of the lake from January through December 1978. All specimens were taken with seines and trawls from 17 different stations representing three habitat types: open lake, shoreline, and marsh. Field observations in conjunction with frequency of occurrence and catch per unit effort figures indicate anchovies were more abundant in open water areas. Length-frequencies show spawning beginning in late March and continuing through late October. Estimates of growth rates were determined. Data indicate a seasonal onshore-offshore movement of anchovies through the tidal passes of the lake. Ecological factors such as temperature and salinity and their effect on the distribution of anchovies was considered.

INTRODUCTION

Anchoa mitchilli Cuvier and Valenciennes, the bay anchovy, was the most abundant fish taken from the Lake Pontchartrain estuary in a 12-month survey ending in December 1978. Norden (1966) and Dugas (1970) listed the bay anchovy among the top four fishes in abundance from

Vermilion Bay, Louisiana. Tarver and Savoie (1976) reported A. mitchilli to be the most abundant fish in the Lake Pontchartrain-Lake Maurepas estuarine complex. Christmas et al. (1973) also listed A. mitchilli as the most abundant fish in the Mississippi Sound estuary.

Trophic analyses of Lake Pontchartrain have shown the bay anchovy to be an important part of the food web. For example, Darnell (1958) found the anchovy in the stomachs of important sport and commercial fishes such as Scianops ocellata (red drum), Micropogonias undulatus (Atlantic croaker), Cynoscion nebulosus (spotted seatrout), and Cynoscion arenarius (sand seatrout). More recently, Levine (Chapter 14) called the bay anchovy "a major link in the trophic web in Lake Pontchartrain." He reported it from stomachs of the above mentioned fishes in addition to the stomachs of of Ictalurus punctatus (channel catfish) and Ictalurus furcatus (blue catfish).

Little life history information exists concerning A. mitchilli in Lake Pontchartrain. Stevenson (1958) reported on its life history in Delaware Bay. Edwards (1967) discussed aspects of the life cycle and seasonal variations in abundance of A. mitchilli in Mississippi Sound. The objective of this report is to provide more information on the biology of A. mitchilli in Lake Pontchartrain. Specific topics considered are:

(1) Spatial and temporal distribution and relative abundance within the lake.

(2) Life cycle and growth within the lake.

(3) Ecological and physical parameters affecting the species within the lake.

MATERIALS AND METHODS

Specimens were taken with seines and trawls on a monthly basis. Primary collecting gear was a 4.8 m wide otter trawl with a cod-end mesh size of 19.1 mm. This was towed behind a 5.9 m Boston Whaler. Engine speed was standardized at 2000 RPM, and trawling times were recorded. Three seines were used to cover shoreline areas: a 3 m long straight seine, mesh size 4.3 mm; a 10.7 m long bag seine with a mesh size of 12.7 mm; and a 45.7 m long bag seine also with a mesh size of 12.7 mm. Selectivity of these gear types could possibly inhibit and bias the sampling. Larval, postlarval, and smaller juveniles were proably inadequately sampled, and data presented underestimate the true size of this portion of the population. Loss of smaller individuals through the coarse netting of the trawls and seines was witnessed on numerous occasions. A few, however, were "trapped" in the meshes and indicate the size range of anchovies present in the estuary at different times of the year.

Every effort was made to cover the same area at each collection station, but this was difficult and even impossible at times due to changes in water depth, snags, and heavy growth of plants. Sampling times were recorded to compute relative efforts expended.

All fishes were preserved immediately in 10% unbuffered formalin. They were allowed to soak 7 to 10 days, rinsed with water one or more times over a five-day period, and stored in 45% isoproponal.

Random samples of a maximum of 25 specimens were individually weighed to the nearest 0.01 gram, and standard length (SL) was measured to the nearest 0.1 mm. The remainder of the sample was counted and weighed. All data were coded for computer analyses.

For the purpose of this report "seasons" shall be defined as:

1) Winter - December, January, and February

2) Spring - March, April, and May

3) Summer - June, July, August, and September

4) Autumn - October and November

STATION LOCATIONS AND DESCRIPTIONS

Station locations are indicated in Figure 1 and are grouped into three habitats: open lake, where all collections were trawls; shoreline, where all collections were seines; and the marsh, where collections were made with seines and trawls as dictated by the physical constraints of the area. Certain stations comprised more than one habitat. Stations are briefly described below.

I. Station One (30° 16.8' N; 90° 16.2' W)

This station was located SW of the mouth of Pass Manchac. It is an open lake station with a water depth of 1-3 m and no apparent vegetation. The bottom was hard mud except the Pass Manchac delta, which was soft silt and mud.

II. Station Two (30° 20.3' N; 90° 16.2' W)

This station was located near the mouth of the Tangipahoa River. It consists of an open lake and shoreline area. Trawls were made approximately 1 km ESE of the mouth of the river, just outside of the power lines. Water depth was 3-3.3 m, and the bottom was hard mud. Seine collections were made at a small shell and mud island immediately to the east of the river mouth. Several types of submerged vegetation were noted here: *Cabomba* sp., *Ceratophyllum* sp., *Myriophyllum* sp., and several filamentous algae.

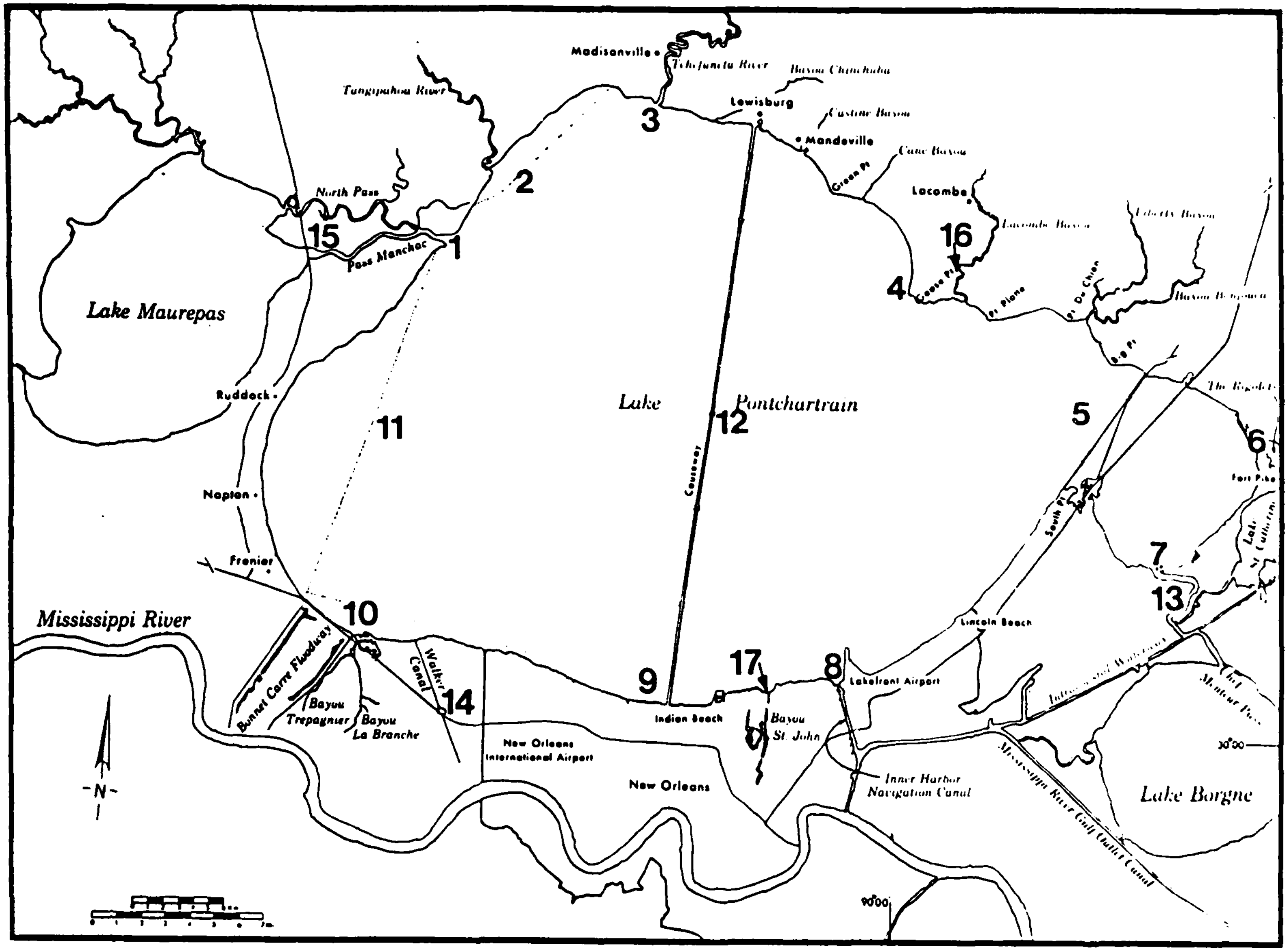


Figure 1. Nekton stations and approximate locations in Lake Pontchartrain, LA 1978.

III. Station Three (30° 22.0' N; 90° 10.8' W)

This station was located off the mouth of the Tchefuncte River. It was an open lake station with a water depth of 2-3.3 m; the bottom is mixed hard clay and mud. There was no observed vegetation.

IV. Station Four (30° 15.6' N; 89° 59.0' W)

This station was located at Goose Point and had both shoreline and open lake areas. Trawls were made 1-2 km west of the shore in water 2-3 m deep. The bottom was soft mud. Seines were made along the beach. Large grassbeds consisting mainly of *Vallisneria americana* mixed with *Najas guadelupensis*, *Ceratophyllum* sp., *Myriophyllum* sp., *Cabomba* sp., and *Cladophera* sp. were noted. The bottom was hard sand.

V. Station Five (30° 11.0' N; 89° 53.5' W)

This station was located midway between Big Point and South Point 1-2 km NW of the railroad bridge. It was an open lake station with a water depth of 2.75-3.3 m. There was no apparent vegetation. Small fragments of the hydroid, *Garveia franciscana*, were occasionally taken. The bottom was soft mud.

VI. Station Six (30° 10.7' N; 89° 44.8' W)

This station was located at the junction of The Rigolets and Lake Pontchartrain and consisted of both shoreline and open lake areas. Trawls were made just inside Lake Pontchartrain in water 2-6 m deep. The bottom here was primarily soft mud. The shoreline area sampled was west of the Highway 90 bridge, along the north shore of the pass. Fairly large grassbeds consisting of *Vallisneria americana* and *Ruppia maritima* were noted. The bottom was mixed hard sand and soft mud.

VII. Station Seven (30° 5.9' N; 89° 49.2' W)

This station was located just inside Lake Pontchartrain at the mouth of Chef Menteur Pass. It was an open lake station with water depths ranging 1-6 m. The bottom was soft mud.

VIII. Station Eight (30° 2.4' N; 90° 2.4' W)

This station was located in Lake Pontchartrain off the mouth of the Inner Harbor Navigation Canal (IHNC). It had both open lake and shoreline areas. The open lake collections were made 1-2 km off the south shore seawall from IHNC mouth west. The water depth ranged from 3-7.3 m. The bottom was soft mud. The shoreline station was at the Seabrook boat ramp and beach. The bottom was concrete at the ramp and sand along the beach. The ramp had large patches of *Enteromorpha* during the warmer months.

IX. Station Nine (30° 2.2' N; 90° 10.0' W)

This station was located in Lake Pontchartrain approximately 1.5 km west of the Causeway and 1.5 km off south shore of Lake Pontchartrain. It was an open lake station with no observed vegetation. The bottom was soft mud.

X. Station Ten (30° 4.3' N; 90° 21.0' W)

This station was located in Lake Pontchartrain near the mouth of Bayou LaBranche and it contained both open lake, parallel to power lines approximately 1.5 km offshore, and shoreline areas along shell, sand, and mud beach just east of the mouth of Bayou LaBranche. The open lake station was 2.0-2.5 m deep with a mud bottom.

XI. Station Eleven (30° 11.8' N; 90° 21.0' W)

This station was located in Lake Pontchartrain midway along the west shore powerlines. It was an open lake station with water depth of 3.0-3.3 m and a soft mud bottom.

XII. Station Twelve (30° 11.3' N; 90° 7.2' W)

This station was located in Lake Pontchartrain along the Causeway near mile marker 12. It was an open lake station. The water was 4.2-4.6 m deep and the bottom was soft mud and shells (Rangia cuneata). There was no apparent vegetation.

XIII. Station Thirteen (30° 0.4' N; 89° 48.7' W)

This station was located in the marsh west of Chef Menteur Pass near Bayou Sauvage. This marsh area was sampled with trawls and seines. Trawls were limited to a shallow, open pond and a large tidal stream. Seining was done in tributaries off the larger tidal stream. The bottom was soft mud, except in the deepest tidal streams, where a hard clay bottom was encountered. This was undoubtedly due to high water velocities scouring the bottom. Water depths varied dramatically according to wind, tide, and rain conditions.

XIV. Station Fourteen (30° 1.6' N; 90° 18.8' W)

This station was located in Walker Canal between Lake Pontchartrain and I-10. This marsh station was a large, man-made canal that was trawled and a small tributary where the seine was employed. Water depth in the canal ranged from 2.0-2.4 m and in the tributary, from 0-1.5 m depending on wind direction and velocity. The bottom in both areas was soft mud and peat. Aquatic vegetation noted was Myriophyllum sp. and Ceratophyllum sp.

XV. Station Fifteen (30° 18.5' N; 90° 23.3' W)

This station was located in North Pass Manchac, Tee Bayou, and adjacent marsh. This marsh station was sampled by seine and trawl. The water depth ranged from 0-1.8 m, and the bottom was soft mud. The aquatic vegetation consisted of Alternanthera philoxeroides, Utricularia sp., and Najas guadalupensis.

XVI. Station Sixteen (30° 16.8' N; 80° 57.3' W)

This station was located in Bayou Lacombe and its adjacent marsh area approximately 1.5 km from Lake Pontchartrain. The main bayou was sampled by trawl; a small tributary was sampled by seine. The water depth ranged from 0-1.8 m; the bottom was soft mud except in a few areas where road shell had spilled over. Cabomba sp., Myriophyllum sp., Ceratophyllum sp., Vallisneria americana, and filamentous green algae were the dominant vegetation types of the bayou and the tributary.

XVII. Station Seventeen (30° 5.0' N; 90° 1.6' W)

This station was located in Lake Pontchartrain at the mouth of Bayou St. John. This shoreline station was sampled from June 1978 through December 1978. It consisted of a firm sand and silt delta to the north of Lakeshore Drive bridge and a densely vegetated area under and to the south of the bridge. The vegetation consisted mainly of Vallisneria americana, Ruppia maritima, Cladophera sp., and Ceratophyllum sp. The water depth ranged from 0-1.8 m.

RESULTS

Anchoa mitchilli were collected throughout the sampling period. A total of 24,449 was taken with trawls and seines. This amounted to 28.8%

of the total finfish catch in numbers. Table 1 indicates the actual number of A. mitchilli taken at each station. A general increase was noted from January to November. A marked decrease occurred in December.

Tables 2 and 3 show the occurrence of A. mitchilli in seine and trawl samples. Also indicated are the number of samples taken and the percentage of samples containing A. mitchilli. Summer (June, July, August, and September) and autumn (October and November) months show a higher success rate than the winter and spring months. Anchovies were present at six stations throughout the year.

Catch per effort (CPE), mean size, size range, and number of collections are shown in Figures 2-5. Also indicated are the approximate station locations. Spring months (March, April, and May) show a slightly higher number of anchovies and a wider distribution but they had not utilized marsh areas as yet. By summer anchovies are distributed throughout the Lake Pontchartrain estuary. In autumn distributions are much the same, with CPE being considerably higher than previous seasons.

Monthly CPEs for selected stations for each gear type are indicated in Figures 6-8. Continuous monthly data are available only for the 4.8 m trawl (Fig. 6). The monthly CPEs are typical of temperate water estuaries where total biomass generally increases until late fall (McHugh 1967). Seining data are intermittent and show no discernable pattern.

Monthly length-frequency polygons (Fig. 9) are typical among fishes with a protracted spawning season. Mean and median lengths change little during the year. The curves, with the exception of April and May, probably indicate continuous recruitment into the Lake Pontchartrain population. The peak, representing the 25.0-29.9 mm size class in March, could indicate early onset of spawning. These individuals undoubtedly

Table 1. Relative Abundance of *Anchoa mitchilli* Population, in Lake Pontchartrain, LA January-December 1978 (by Station)

Sta #	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Max.	$\bar{X}$	Min.
1		1	44		1	202	30	147	357		169	7	357	79.8	0
2		1	127		19	250	77	161	254	355	306	12	355	130.2	0
3			5	134	4	284	51	27	173	270	459	7	459	117.8	0
4	19	69	93	10	105	103	144	314	126	492	154	5	492	136.2	5
5	2	141	17	22	154	53	209	136	52	30	46	66	209	77.3	2
6	39	12	33	345	46	141	171	152	280	152	370	50	370	149.3	12
7	36	3	6	3	81	83	182	34	74	132	28	41	182	58.6	3
8	19	155	4	266	346	71	188	280	92	406	31	115	406	164.4	4
9	10	3	8	28	5	27	296	421	323	781	48	1	781	162.6	1
10		1	167	345	74	264	821	1087	617	483	931	111	1087	408.4	0
11			180	2	2		72	78	182	444	877	47	877	157	0
12		139		32	14	173	165	214	246	155	488	50	488	139.7	0
13		1					22		136	9	27		136	16.3	0
14		1	2	515	20	86	393	132	129	117	540	78	540	167.8	0
15			2	1				2	1				2	0.5	0
16				4		53	62				248	138	248	42.1	0
17	←NO SAMPLES TAKEN→					368	106	104	31	57	2	23	368	98.7	2
TOTAL	125	527	688	1362	871	2158	2989	3289	3[illegible]	[illegible]	4724	751			

Table 2. Presence and Absence of *A. mitchilli* in Trawl Collections from Lake Pontchartrain, LA during 1978

Station #	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	# of samples w/anchovies / Total # of samples	%
1	-	+	+	-	+	+	+	+	+	-	+	+	9/12	75
2	-	+	+	-	-	+	+	+	+	+	+	+	9/12	75
3	-	-	+	+	+	+	+	+	+	+	+	+	10/12	83.5
4	+	+	+	+	+	+	+	+	+	+	+	+	12/12	100
5	+	+	+	+	+	+	+	+	+	+	+	+	12/12	100
6	+	+	+	+	+	+	+	+	+	+	+	+	12/12	100
7	+	+	+	+	+	+	+	+	+	+	+	+	12/12	100
8	+	+	+	+	+	+	+	+	+	+	+	+	12/12	100
9	+	+	+	+	+	+	+	+	+	+	+	+	12/12	100
10	-	-	+	+	+	+	+	+	+	+	+	+	10/12	83.3
11	-	-	+	+	+	-	+	+	+	+	+	+	9/12	75.0
12	-	+	-	+	+	+	+	+	+	+	+	+	10/12	83.3
13	-	+	-	-	-	-	+	*	*	+	+	*	4/9	44.4
14	-	+	+	+	+	+	+	+	+	+	+	+	11/12	91.7
15	-	-	+	+	-	-	*	+	+	*	*	*	4/8	50.0
16	-	-	-	-	-	+	*	*	*	*	+	+	3/8	37.5
17	← NOT SAMPLED BY TRAWL →													
**Σ	6/16	11/16	13/16	12/16	12/16	13/16	14/14	14/14	14/14	13/14	15/16	14/16		

*No sample taken.

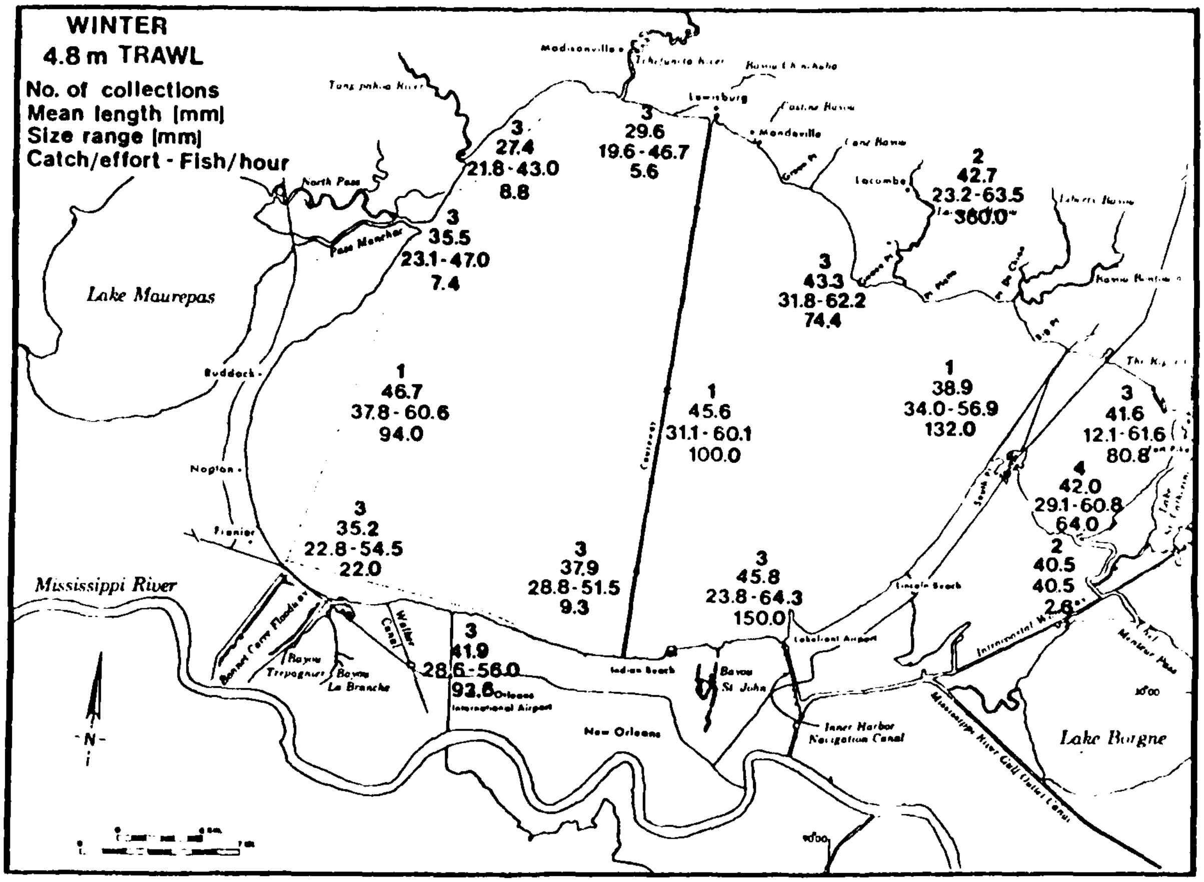
**Σ Row means number of times species was present over number of possible occurrences.

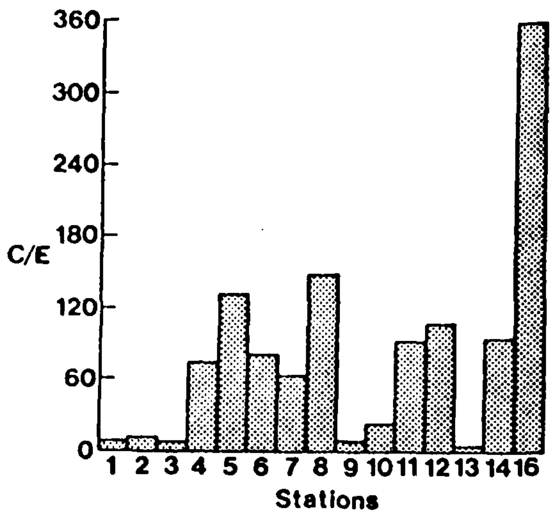
Table 3. Presence and Absence of *A. mitchilli* in Seines from Lake Pontchartrain, LA 1978

Station #	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	# of samples w/anchovies / Total # of samples	%
1														
2	–	–	+	–	+	+	+	+	+	+	+	+	9/12	75.0
3	–	–	← DISCONTINUED →											
4	–	–	+	–	+	+	+	–	+	–	–	–	5/12	41.7
5														
6	–	–	+	+	+	+	+	+	+	+	+	+	10/12	83.3
7														
8	+	+	–	+	+	+	–	+	–	+	+	+	9/12	75.0
9														
10	*	+	*	+	–	+	+	+	+	+	+	+	9/10	90
11														
12														
13	–	–	–	–	–	–	–	–	+	–	*	*	1/10	10.0
14	–	–	+	+	–	+	+	+	+	+	+	+	9/12	75.0
15	*	–	–	–	–	–	–	–	–	*	*	*	0/8	0
16	*	–	–	+	–	–	+	–	*	–	–	*	2/9	22.2
17	← NOT SAMPLED →					+	+	+	+	–	+	+	6/7	85.7
**Σ	1/7	2/10	4/8	5/9	4/9	7/10	7/10	6/10	7/9	5/9	6/8	6/7		

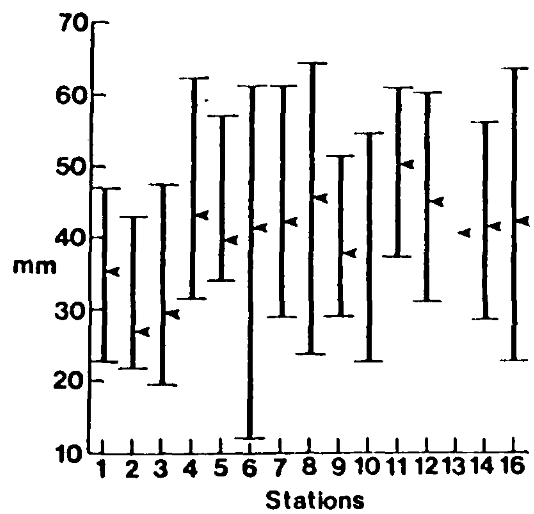
*No sample taken.

**Σ row means number of times species was present over number of possible occurrences.



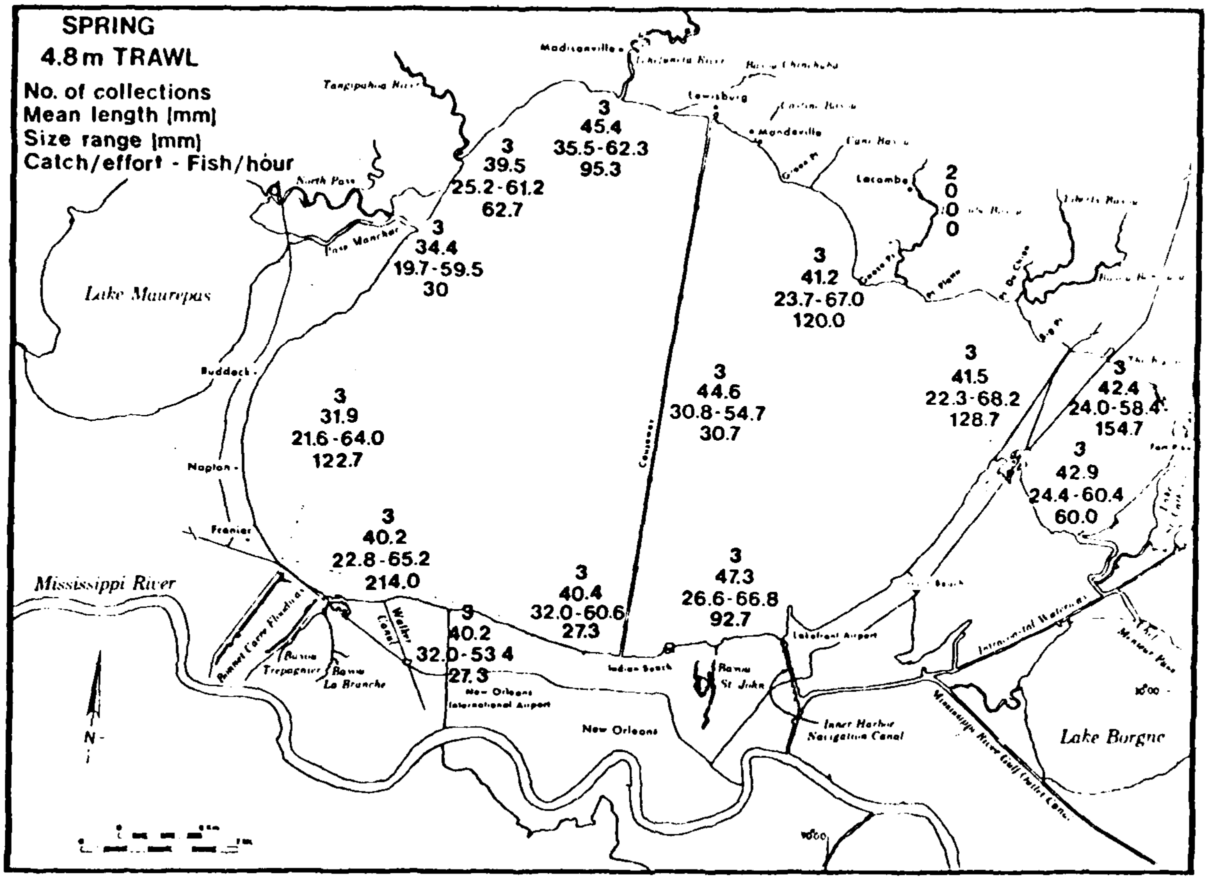


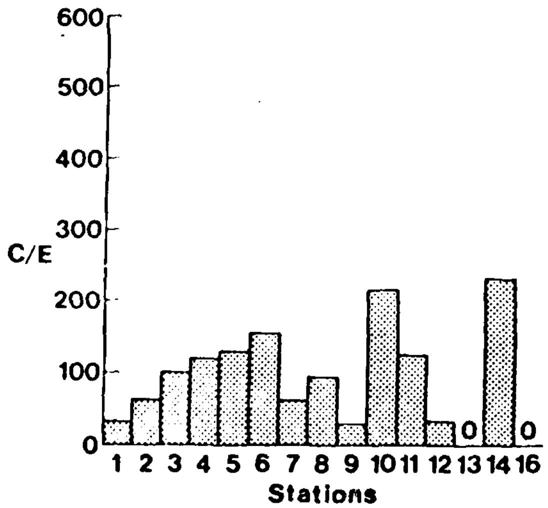
Catch Per Unit Effort of A. mitchilli Taken with 4.8 m Trawl



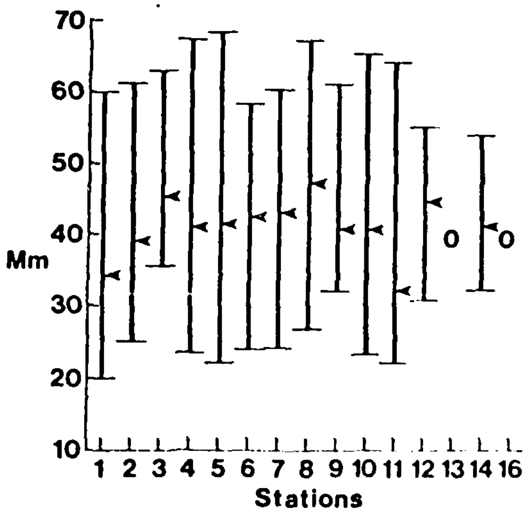
Mean Length and Size Ranges of A. mitchilli

Figure 2. Distribution of A. mitchilli within Lake Pontchartrain, LA, and adjacent marshes during winter (December, January, and February) 1978. Catch per effort and size data are also illustrated by bar graphs. For station locations, compare with Figure 1.



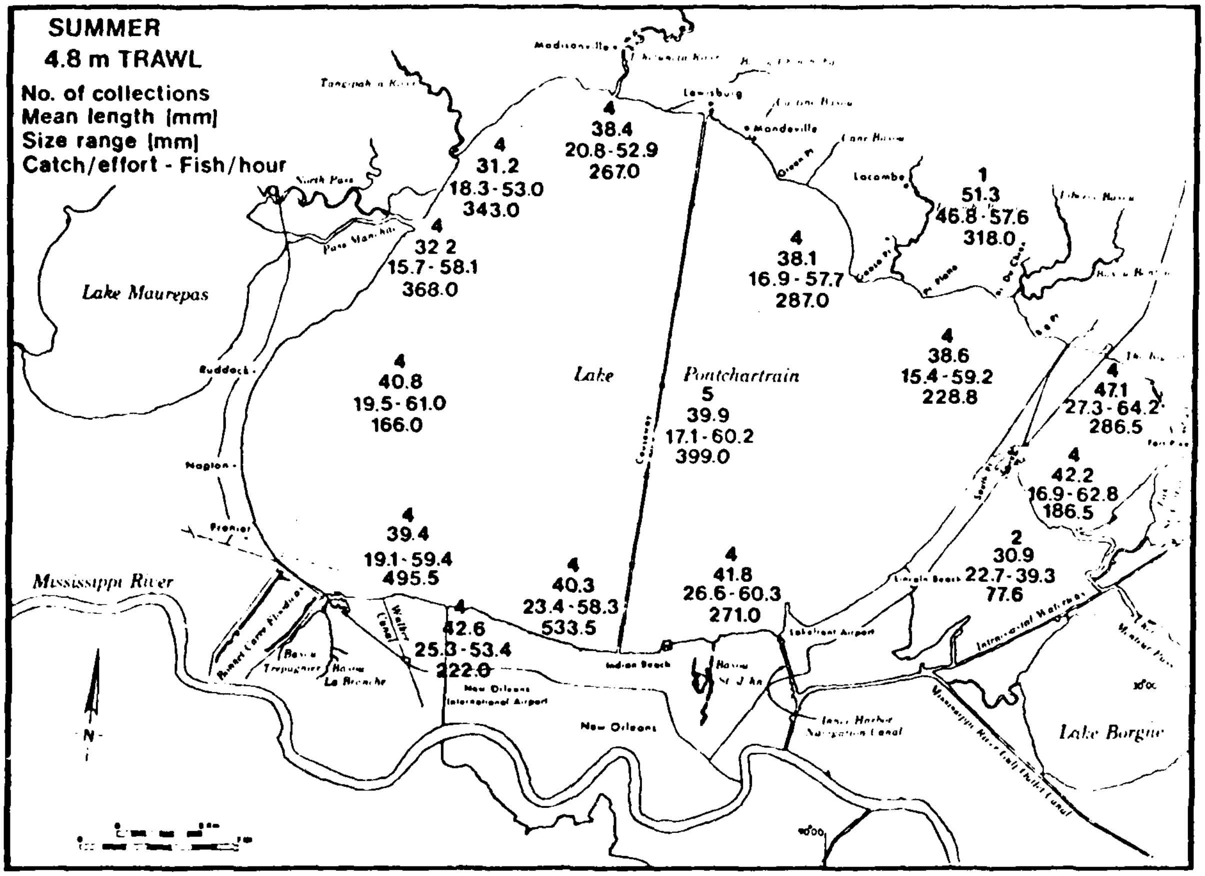


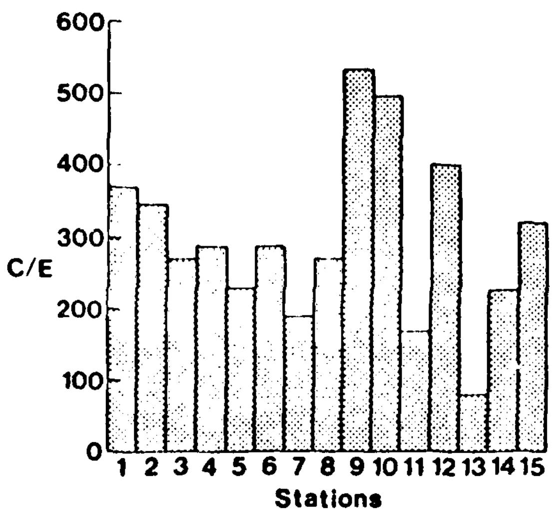
Catch Per Unit Effort of A. mitchilli Taken with 4.8 m Trawl



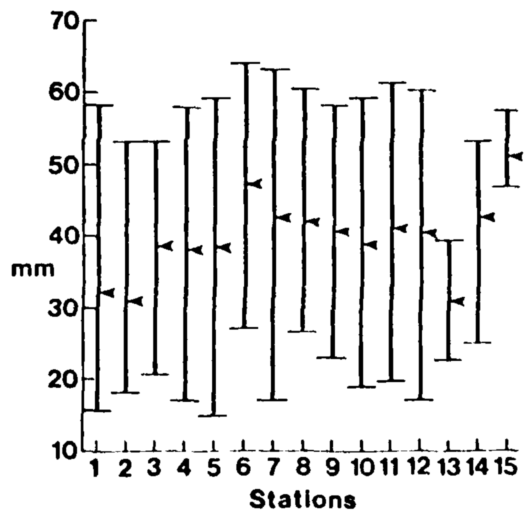
Mean Length and Size Ranges of A. mitchilli

Figure 3. Distribution of A. mitchilli within Lake Pontchartrain, LA, and adjacent marshes during spring (March, April, and May) 1978. Catch per effort and size data are also illustrated by bar graphs. For station location, see Figure 1.



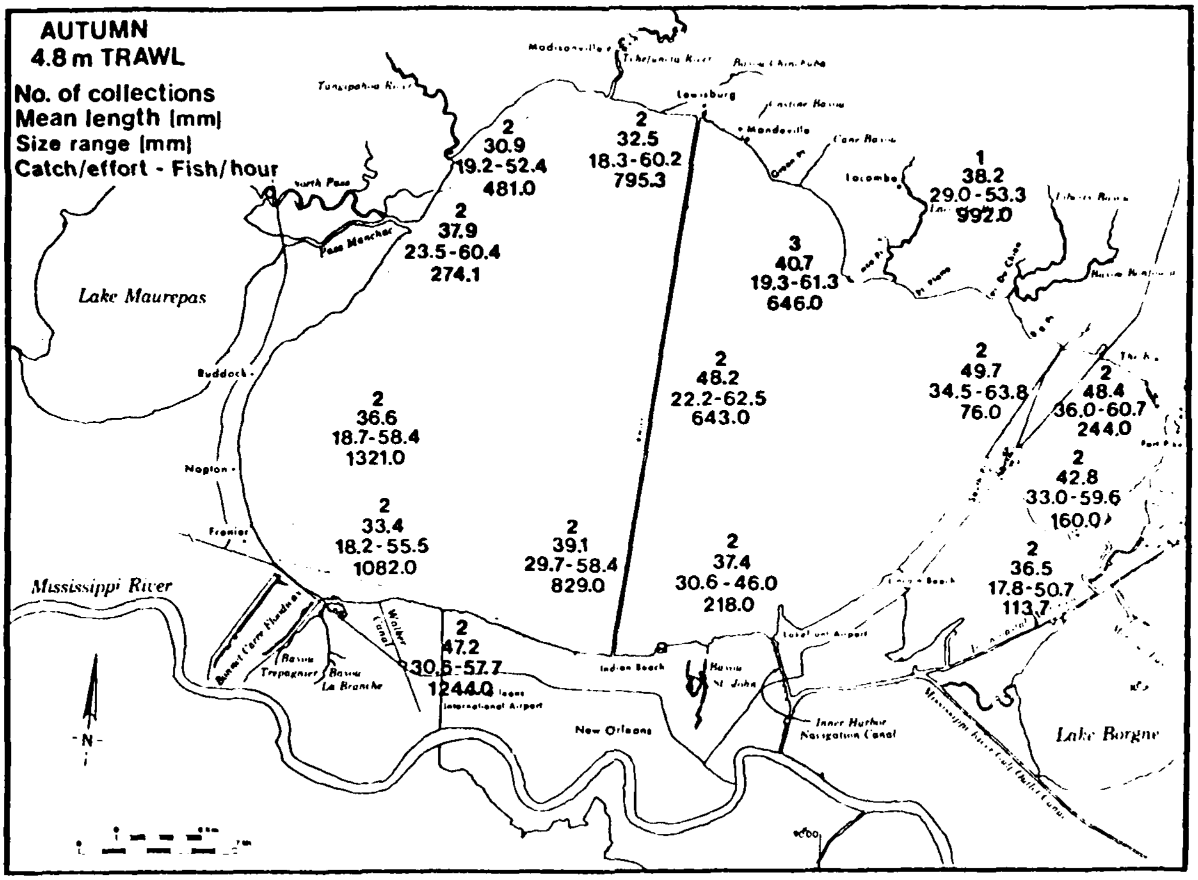


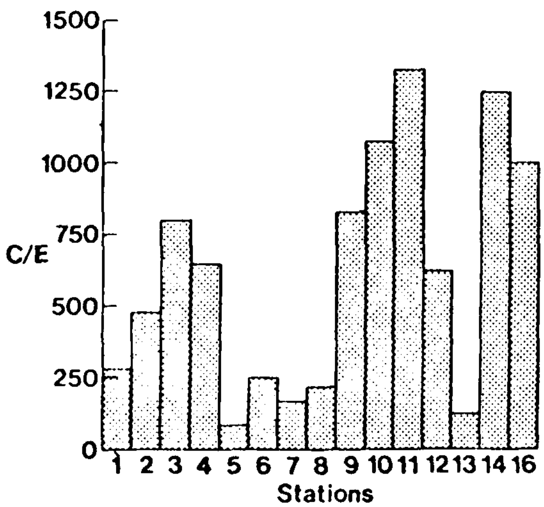
Catch Per Unit Effort of
A. mitchilli Taken
with 4.8 m Trawl



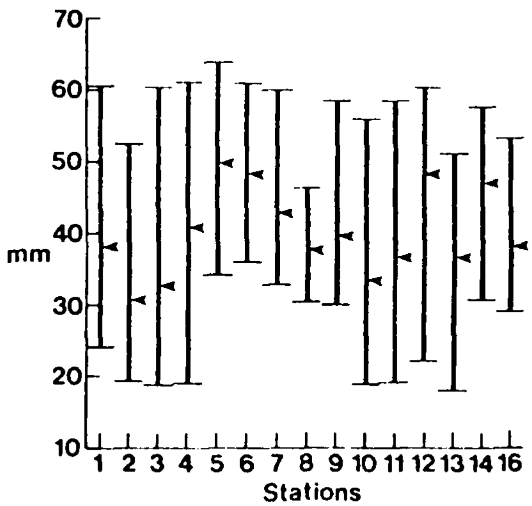
Mean Length and Size Ranges
of A. mitchilli

Figure 4. Distribution of A. mitchilli within Lake Pontchartrain, LA, and adjacent marshes during summer (June, July, August, and September) 1978. Catch per effort and size data are illustrated by bar graphs. For station locations, see Figure 1.





Catch Per Unit Effort of
A. mitchilli Taken
with 4.8 m Trawl



Mean Length and Size Ranges
of A. mitchilli

Figure 5. Distribution of A. mitchilli within Lake Pontchartrain, LA, and adjacent marshes during autumn (September and October) 1978. Catch per effort and size data are illustrated by bar graphs. For station locations, see Figure 1.

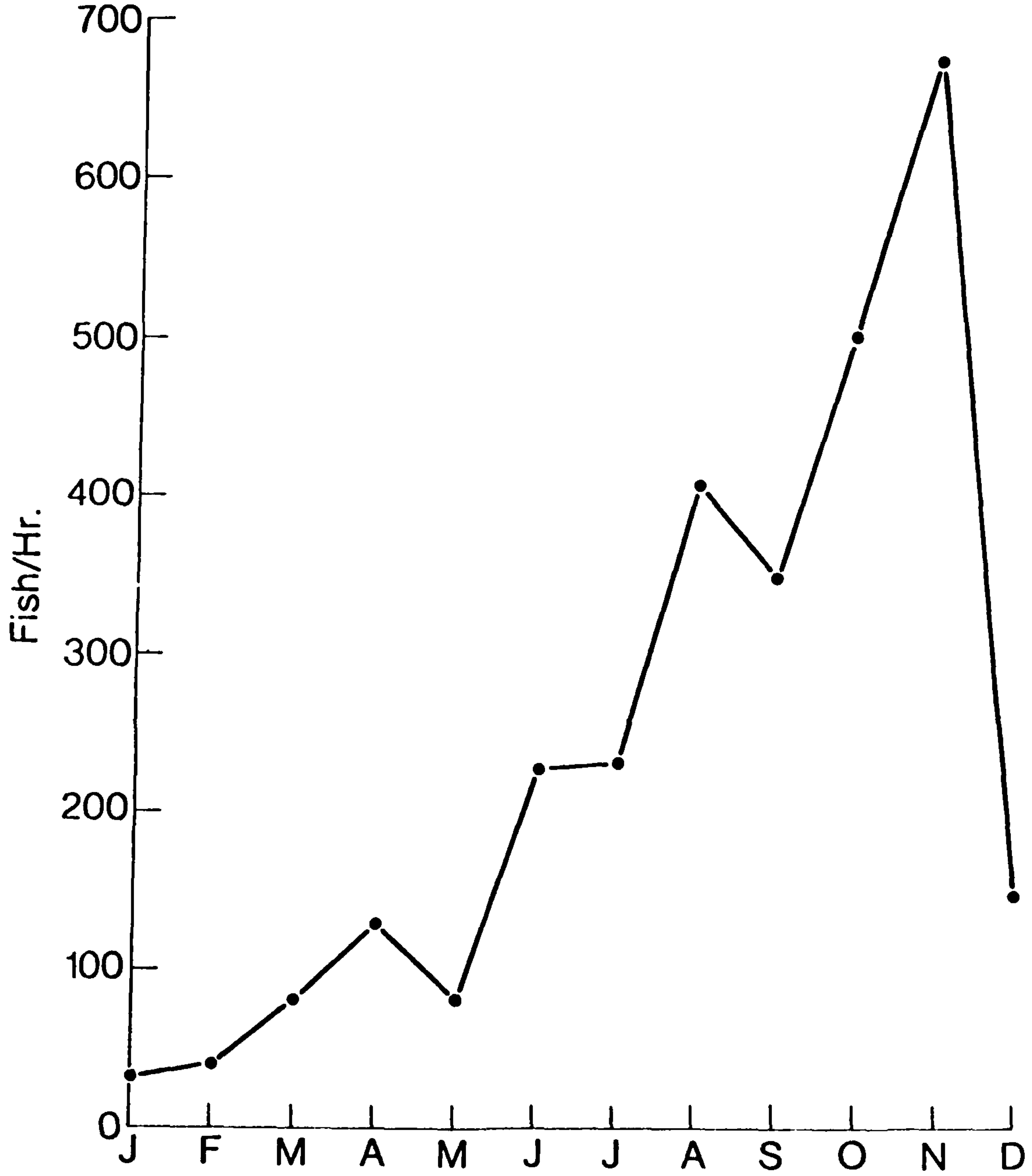


Figure 6. Mean monthly catch per unit effort for A. mitchilli taken with 4.8 m trawl in Lake Pontchartrain, LA, during 1978.

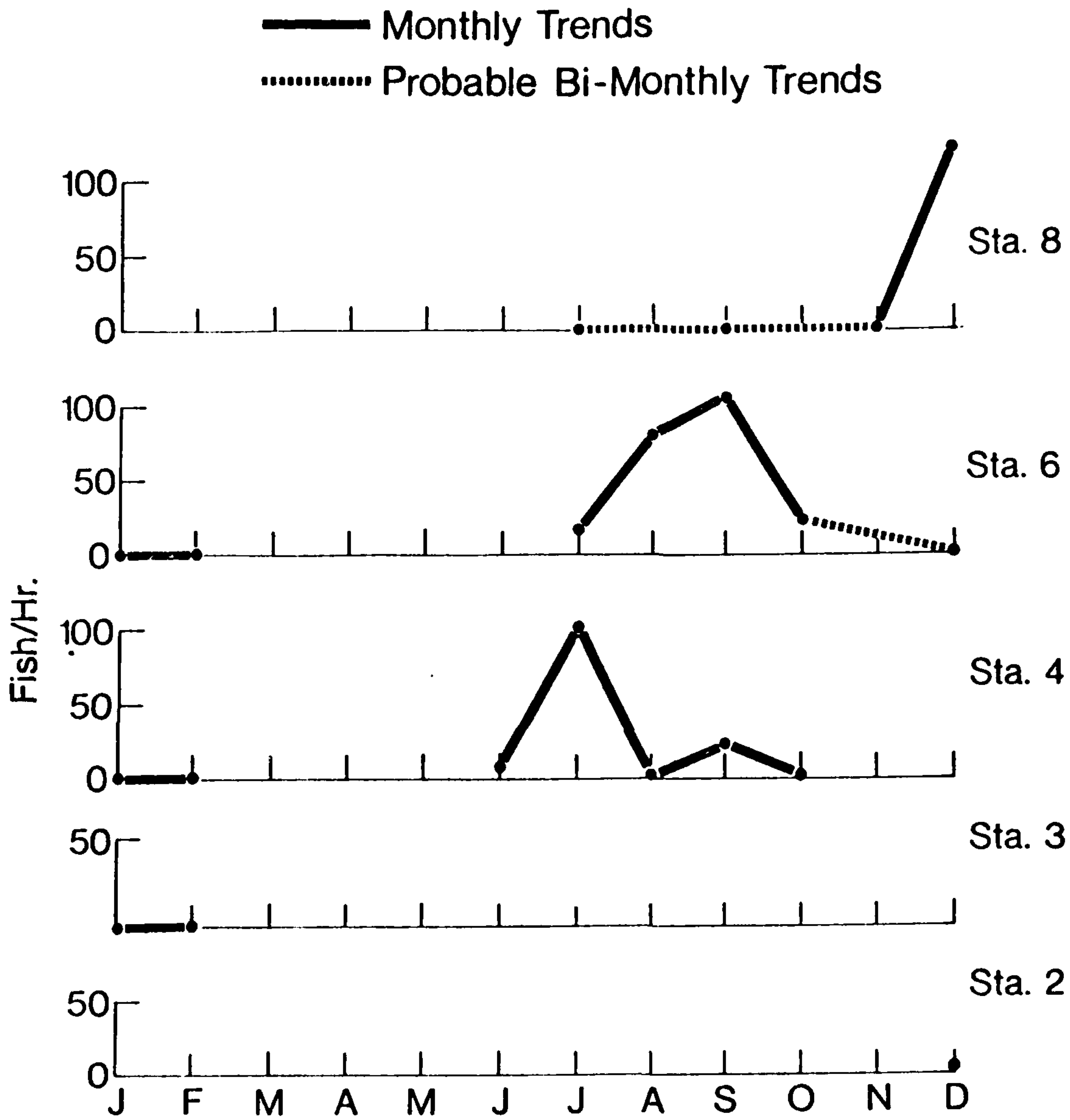


Figure 7. Mean monthly catch per unit effort for _A. mitchilli_ with 3 m seine in Lake Pontchartrain, LA, during 1978.

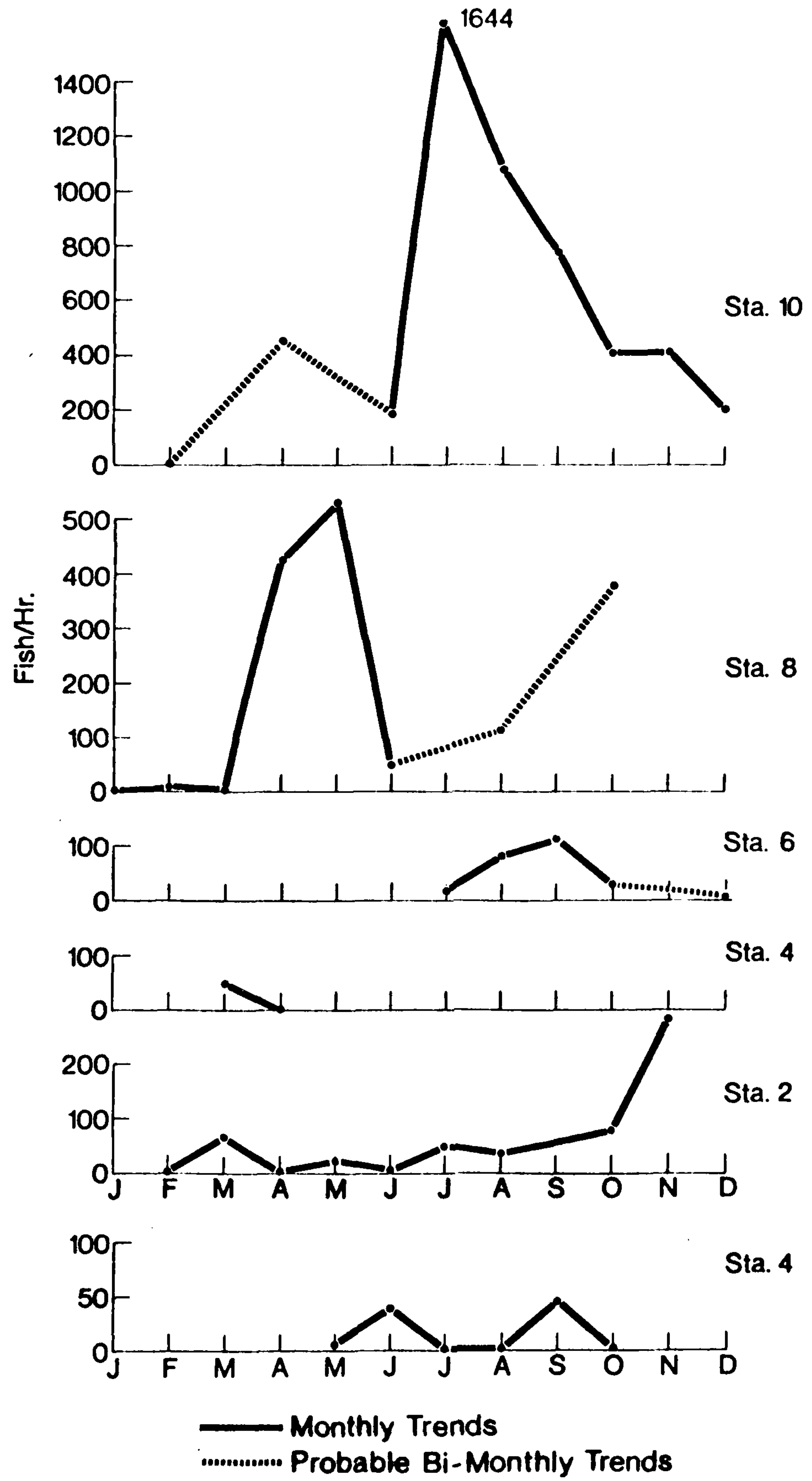


Figure 8. Mean monthly catch per unit effort for A. mitchilli with 10.7 m bag seine in Lake Pontchartrain, LA, during 1978. The lower figure for Station 4 gives mean monthly catch per unit effort for A. mitchilli with 45.7 m bag seine.

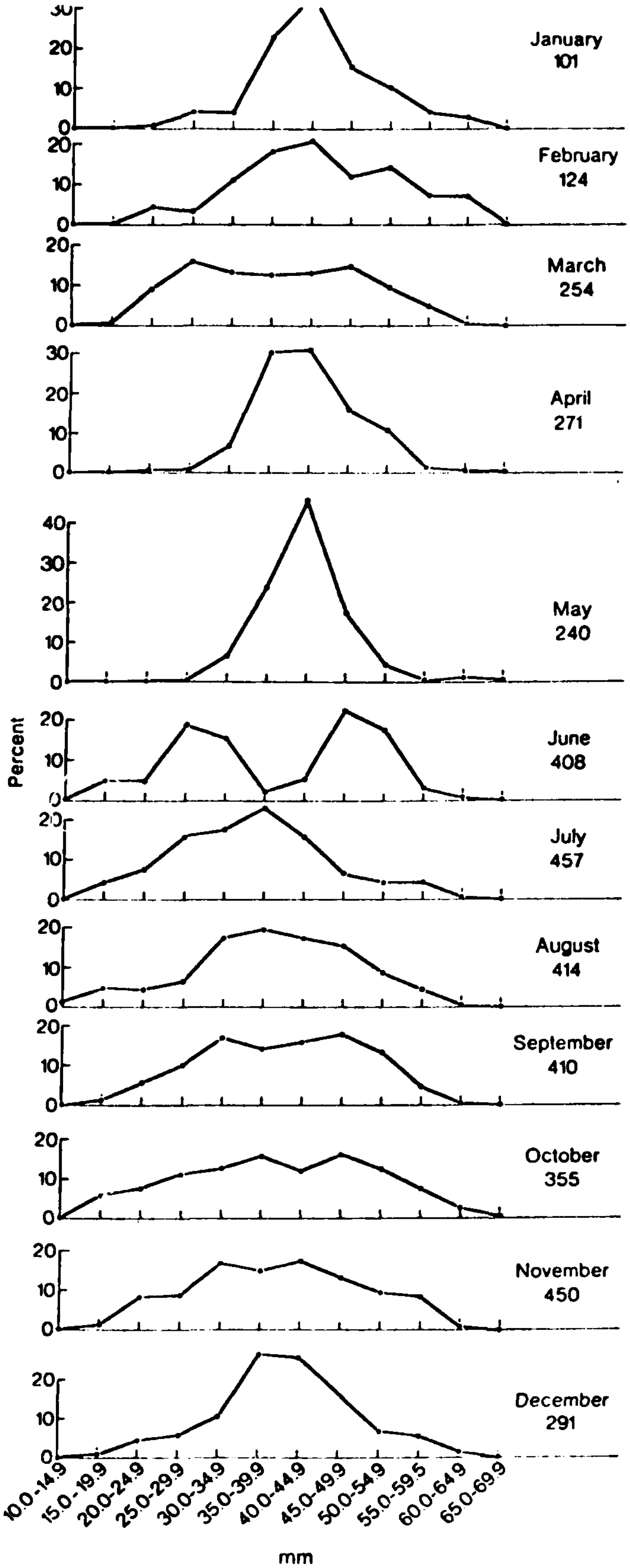


Figure 9. Length-frequency of Anchoa mitchilli taken from all stations in Lake Pontchartrain (1978) with number of specimens measured indicated.

were spawned in late 1977, overwintered outside Lake Pontchartrain, then moved into the lake. The peak, representing the above-size class, in June are individuals spawned in late April or early May, judging from growth rates reported by Edwards (1967) on Mississippi Sound anchovies and Stevenson (1958) on A. mitchilli in Delaware Bay. Data did not indicate spawning within the lake.

Tables 4-7 indicate distribution of A. mitchilli with respect to temperature and salinity. Anchovies were found in all salinities sampled, with the greatest density in the 2.0-3.9 $^o/_{oo}$ range. Temperature appeared to have the greater affect on the distribution, with the greatest numbers occurring in the 20.0-29.9 °C range.

DISCUSSION

Anchoa mitchilli was the most commonly occurring finfish in Lake Pontchartrain during 1978. From the monthly distribution patterns, it is evident that young anchovies move into the lake through the tidal passes early in the year. This movement continues until late autumn or early winter, when mass emigration presumably occurs. Seasonal onshore-offshore migration was first reported by Hildebrand (1943) and later by Gunter (1945), Stevenson (1958), and Edwards (1967). There is evidence of an offshore (gulfward) movement of larger anchovies through the tidal passes (Fannaly, Chapter 15) indicating that the estuary functions as a nursery for newly spawned individuals.

Anchovies were found to occupy all habitats sampled, especially open lake areas, the tidal passes, which had anchovies year round. Marsh and shoreline areas were not sampled consistently enough to statistically test for differences in distribution, but field observations indicated anchovies were more abundant in open water areas of the lake.

Table 4. Catch Data on A. mitchilli in Terms of Salinity (°/..) and Temperature (°C). Data Include Number of Samples, Catch per Unit Effort (CPE), Size Range (mm), and Mean Size (mm) of Fishes Taken with a 4.8 m Trawl in Lake Pontchartrain, LA During 1978

Salinity (°/..)		Temp. °C						
		5.0-9.9	10.0-14.9	15.0-19.9	20.0-24.9	25.0-29.9	30.0+	Totals
0.0-1.9	Smpls	11	25	1	12	13	5	67
	CPE	12.8	89.6	0	262.6	369.0	204.9	179.2
	Min-Max	23.1-64.3	19.6-67.0	0	18.3-60.4	15.7-58.1	18.3-62.8	15.7-67.0
	Mean	41.3	37.4	0	34.8	37.7	40.7	37.1
2.0-3.9	Smpls	8	9	2	26	21	12	78
	CPE	60.0	90.1	85.0	414.0	398.3	247.3	308.5
	Min-Max	12.1-61.6	22.8-60.6	30.8-66.8	18.2-63.8	15.4-64.2	16.9-62.3	12.1-66.8
	Mean	42.9	42.6	48.1	41.6	42.4	38.5	41.5
4.0-5.9	Smpls		1		9	9	2	21
	CPE		82.0		268.6	242.6	191.0	239.0
	Min-Max		29.1-52.6		17.8-68.2	16.9-62.8	31.0-64.0	16.9-68.2
	Mean		38.8		44.2	40.7	43.2	42.1
6.0-7.9	Smpl				1			1
	CPE				56.0			56.0
	Min-Max				33.0-59.6			33.0-59.6
	Mean				40.8			40.8
8.0-8.5	Smpls							
	CPE							
	Min-Max							
	Mean							
8.5 +	Smpls				1			1
	CPE				216.0			216.0
	Min-Max				36.0-59.3			36.0-59.3
	Mean				47.0			47.0
TOTALS	Smpls	19	35	3	48	43	19	
		32.2	89.5	56.7	339.4	359.1	230.2	
	Min-Max	12.1-64.3	19.6-67.0	30.8-66.8	17.8-68.2	15.4-64.2	16.9-64.0	
	Mean	42.4	39.4	48.1	40.9	40.5	38.3	

Table 5. Catch Data on *A. mitchilli* in Terms of Salinity (°/₀₀) and Temperature (°C). Data Include Number of Samples, Catch per Unit Effort (CPE), Size Range (mm), and Mean Size (mm) of Fishes Taken with a 3 m Straight Seine in Lake Pontchartrain, LA During 1978

Salinity (°/₀₀)		Temp. °C						
		5.0-9.9	10.0-14.9	15.0-19.9	20.0-24.9	25.0-29.9	30.0-34.9	Totals
0.0-1.9	Smpls	5	9	1	3	7	3	28
	CPE	0	0.8	12.0	0	24.0	0	7.0
	Min-Max	0	35.2-47.7	35.1-47.7	0	21.8-50.5	0	21.8-50.5
	Mean	0	40.1	39.0	0	38.2	0	38.3
2.0-3.9	Smpls	3	3		7	4	6	23
	CPE	0	16.0		10.9	84.0	303.4	93.4
	Min-Max	0	31.9-49.4		16.3-56.3	24.4-54.0	12.3-56.0	12.3-56.0
	Mean	0	41.8		43.1	37.4	32.4	37.0
4.0-5.9	Smpls		2		4	6	4	16
	CPE		91.3		22.5	33.8	120.0	52.8
	Min-Max		25.1-62.3		24.0-54.6	15.4-59.0	34.6-49.4	15.4-59.0
	Mean		41.9		47.4	35.9	42.2	40.6
6.0-7.9	Smpls				1	1		2
	CPE				0	272.0		148.4
	Min-Max				0	24.7-53.5		24.7-53.5
	Mean				0	38.2		38.2
8.0- +	Smpls							
	CPE							
	Min-Max							
	Mean							
TOTALS	Smpls	8	14	1	15	18	13	
	CPE	0	14.3	12.0	11.2	53.7	168.0	
	Min-Max	0	25.1-62.3	35.1-47.7	16.3-56.3	15.4-59.0	12.3-56.0	
	Mean	0	41.7	39.0	45.0	37.3	36.4	

Table 6. Catch Data on *A. mitchilli* in Terms of Salinity (°/..) and Temperature (°C). Data Include Number of Samples, Catch per Unit Effort (CPE), Size Range (mm), and Mean Size (mm) of Fishes Taken with a 10.7 m Bag Seine in Lake Pontchartrain, LA During 1978

Salinity (°/..)		Temp. °C						
		5.0-9.9	10.0-14.9	15.0-19.9	20.0-24.9	25.0-29.9	30.0-34.9	Totals
0.0-1.9	Smple	2	7		4	3	2	18
	CPE	0.6	37.1		174.0	26.0	15.0	62.4
	Min-Max	54.2-54.2	29.0-57.0		23.8-47.0	23.0-42.1	17.5-33.6	17.5-57.0
	Mean	54.2	44.8		35.5	32.0	26.5	37.6
2.0-3.9	Smple		1		5	4	1	11
	CPE		32.1		332.6	682.7	1087.2	505.6
	Min-Max		37.4-59.0		24.9-59.1	21.9-55.4	27.4-61.7	21.9-61.7
	Mean		50.9		41.3	39.5	42.2	41.4
4.0-5.9	Smple					1	2	3
	CPE					373.7	71.2	167.5
	Min-Max					16.0-45.0	13.0-49.0	13.0-49.0
	Mean					23.1	29.5	27.2
6.0-7.9	Smple							
	CPE							
	Min-Max							
	Mean							
8.0- +	Smple				1			1
	CPE				524.0			524.0
	Min-Max				21.0-63.4			21.0-63.4
	Mean				44.4			44.4
TOTALS	Smple	2	8		10	8	5	
	CPE	0.6	36.5		273.1	413.8	208.8	
	Min-Max	54.2-54.2	29.0-59.0		21.0-63.4	16.0-55.4	13.0-61.7	
	Mean	54.2	45.8		39.3	35.0	32.5	

Table 7. Catch Data on *A. mitchilli* in Terms of Salinity (°/..) and Temperature (°C). Data Include Number of Samples, Catch per Unit Effort (CPE), Size Range (mm), and Mean Size (mm) of Fishes Taken with a 45.7 m Bag Seine in Lake Pontchartrain, LA During 1978

Salinity (°/..)		Temp. °C 5.0-9.9	10.0-14.9	15.0-19.9	20.0-24.9	25.0-29.9	30.0-34.9	Totals
0.0-1.9	Smpls					2		2
	CPE					27.7		27.7
	Min-Max					41.0-54.3		41.0-54.3
	Mean					50.2		50.2
2.0-3.9	Smpls	1			4	2	3	10
	CPE	0			5.6	52.2	11.4	17.1
	Min-Max	0			35.0-60.3	15.4-64.4	31.5-52.0	15.4-64.4
	Mean	0			41.9	31.4	44.7	37.7
4.0-5.9	Smpls							
	CPE							
	Min-Max							
	Mean							
6.0-7.9	Smpls							
	CPE							
	Min-Max							
	Mean							
8.0-8.9	Smpls							
	CPE							
	Min-Max							
	Mean							
TOTALS	Smpls	1			4	4	3	
	CPE	0			5.6	41.6	11.4	
	Min-Max	0			35.0-60.3	15.4-64.4	31.5-52.0	
	Mean	0			41.9	36.8	44.7	

Relative percentage of anchovies in the total finfish catch monthly and seasonally is indicated in Table 8. A continual increase in percentages is apparent starting during the spring months. The slight reduction in numbers of A. mitchilli taken during spring compared to winter could be attributed to many factors. For example, sampling trips during those months often coincided with or were preceded by periods of heavy rainfall. (Rainfall data for East Central and Southeast section of Louisiana from National Oceanic and Atmospheric Association [NOAA] Climatological Data-Louisiana 83 [1-12] 1978). Increased discharges from rivers and urban areas of the Lake Pontchartrain drainage could have altered the water quality so that anchovies may have been adversely affected. Increased discharges through the tidal passes could impede immigration of the fishes. When this period coincides with the onset of spawning, another possibility for reduction could be postspawning die-off, with some larger anchovies dying off before the intense recruitment into the lake population from this year's spawning.

Analysis of the length-frequency curves for A. mitchilli within the lake gives only an estimate of the growth rate. As pointed out by other researchers (Hildebrand and Cable 1930, Christmas et al. 1973), growth of A. mitchilli is difficult to determine because of the extended spawning period and continuous recruitment of young into the population. This problem is compounded because the population of A. mitchilli in the lake is made up of individuals that probably have migrated from populations existing in Mississippi Sound, Lake Borgne, and Breton Sound. The changes in distribution in March and April indicate a growth rate of 11-12 mm per month. Between May and June and between June and July the growth rate was 7-9 mm per month; the average growth rate for this period

Table 8. Percentage of *A. mitchilli* in Trawls and Seines, Stations 1-12 and 17 from Lake Pontchartrain, LA During 1978

Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	$\bar{X}$
15.8	27.6	22.3	17.9	13.3	33.6	30.1	44.8	42.1	60.6	63.5	15.9	32.3

Winter (DJF)	Springs (MAM)	Summer (JJAS)	Autum (ON)
19.8	17.8	37.7	62.1

is 9 mm per month. This is in agreement with the growth rate reported by Edwards (1967) for A. mitchilli in Mississippi Sound. More accurate growth rates could be determined by an intensive mark and recapture study.

Edwards (1967) reported a growth of 16 mm in the first month of their life cycle for A. mitchilli in the Mississippi Sound. Since Fannaly (Chapter 15) has shown immigration of 18.8-21.7 mm anchovies during the months May to October through the passes of Lake Pontchartrain, it is possible to conclude that spawning begins in late March or early April. The continued appearance of the 15-20 mm size classes well into November and their virtual absence in December probably indicate a cessation of spawning in late October to early November (Fig. 10).

A. mitchilli has been reported in waters with salinities ranging 0.5-31.5 ppt (Edwards 1967). My data agree with that of other researchers and indicate a wide salinity tolerance by A. mitchilli. There is an indication of a higher salinity preference of larger individuals, but this could not be tested statistically.

The effect of temperature on the distribution of anchovies is apparent. Waters of temperatures below 20°C produced few individuals. Small numbers of anchovies from shallow waters in colder weather were reported by Hildebrand and Schroeder (1927) and Stevenson (1958).

Anchoa mitchilli is thought to be an estuarine-dependent fish. Although young have been found at high salinities (Gunter 1945), the greatest numbers usually occur in lower salinities. Other factors common to estuarine areas that could also be responsible for the distribution of young anchovies are high turbidities, shallow waters, and access to protective vegetated areas. Reid (1956) suggests "that bottom

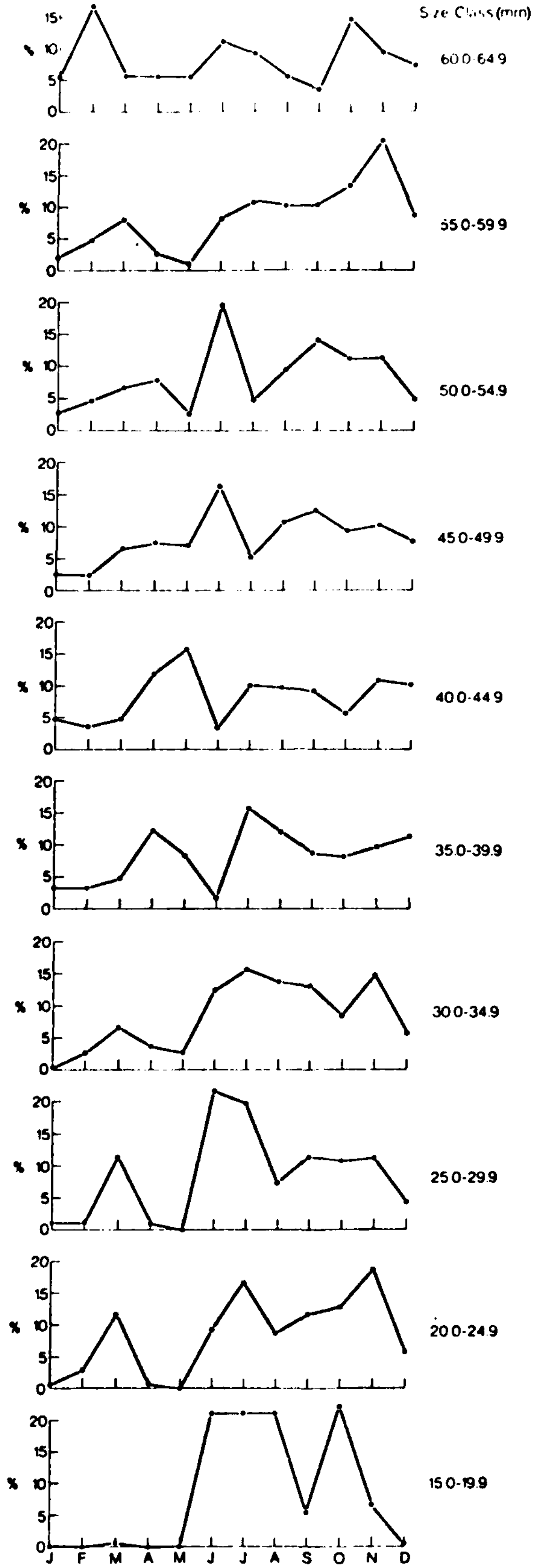


Figure 10. Relative frequency within size classes of A. mitchilli taken from Lake Pontchartrain, LA, in 1978.

composition (its relation to food production and cover) and depth are important factors in the ecology of *A. mitchilli diaphana*."

SUMMARY

Anchoa mitchilli is one of the most abundant estuarine-dependent fishes in Lake Pontchartrain. Its residency in the estuary is generally from spring through late autumn. The open water of the lake is the preferable habitat, but they occupy all areas in the estuary.

Specimens taken as small as 12 mm SL indicate movement into the lake soon after spawning that begins in late March and continues through late October. Availability of food and protection offered by aquatic vegetation and turbid waters are probably two important factors influencing the movement of young-of-the-year anchovies into Lake Pontchartrain. Because very few specimens larger than 60 mm SL were taken, it was assumed that these individuals move out of the lake on a continuous basis, however, mortality (natural and man-induced) could be a factor here also. Preliminary evidence indicates that mass emigration occurs during late autumn. Reduction in water temperature from an average of about 22° C in November to an average of about 11°C in December may be responsible.

At present, *A. mitchilli*'s importance to man is indirect. It is utilized as food by many commercial and sport fishes (such as *Cynoscion nebulosus*). Alteration and reduction of the population of *A. mitchilli* within Lake Pontchartrain would alter feeding patterns of many fishes.

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Modern camp and bulkhead near Lacombe, Louisiana

Man-made channel near Lacombe, Louisiana

Chapter 14

GUT CONTENTS OF FORTY-FOUR LAKE PONTCHARTRAIN, LOUISIANA, FISH SPECIES

by

Steven J. Levine

ABSTRACT

Gut contents of 2135 specimens, comprising more than 40 species of Lake Pontchartrain fishes, were analyzed. Variation in food and feeding with respect to habitat, growth, and interspecific factors was studied for *Anchoa mitchilli*, *Cynoscion nebulosus*, *Cynoscion arenarius*, *Micropogonias undulatus*, *Leiostomus xanthurus*, *Ictalurus furcatus*, *Ictalurus punctatus*, and *Menidia beryllina*. Limited diel studies of *Strongylura marina* and *Membras martinica* showed a relationship between feeding and tidal cycle. Data where applicable are compared with Darnell (1958). Two trophic pathways are described, the first based upon infaunal and benthic food organisms and the second based upon planktonic and nektonic forms. Generalized feeding prevailed among fishes, and specialization when observed was usually a temporary, growth-related condition. The importance of aquatic vegetation beds as habitat for food organisms and fishes (particularly in urban areas) and the potential for ecological imbalance among Lake Pontchartrain fishes caused by increased man-made substrates and higher turbidities are discussed.

INTRODUCTION

Much ecological information about an estuary is available from the study of the food habits of its fishes. Food and feeding figure

prominently in fish distribution and behavior (Bailey and Harrison 1948). Fishes may be used as "collecting gear" for other organisms. Several new species of water mite, for example, were described from stomach contents of trout (Pennak 1953).

The studies of Darnell (1958, 1961, 1962, and Darnell and Meierotto 1962) comprise the sole multispecies trophic research on the fishes of the Lake Pontchartrain estuary. Human impact on the estuary has steadily increased, and physicochemical conditions have changed since the mid-1950's. Turbidity, for example, has increased. The 1953-1954 mean Secchi disc visibility reported by Suttkus et al. (1954) was approximately 114 cm; often maxima of 500-plus cm were recorded. In the present 1977-1978 study, comparable figures were 69 cm mean and a 195 cm maximum value.

OBJECTIVES

Darnell's (1958) work in Lake Pontchartrain over 25 years ago remains relevant as a baseline for the present study. Whenever applicable, my results will be compared with those obtained by Darnell (ibid.). Several littoral and marsh fishes not covered in previous research will also be analyzed. Discussions will include aspects of trophic ontogeny and geographic variation in feeding for some fish species.

MATERIALS AND METHODS

Specimens for food analysis were collected with trawls, seines, gill and trammel net, dipnet, and electroshocking gear between November 1977 and September 1978. A total of 2135 specimens comprising 44 species was examined (Table 1). Species prone to regurgitation were stunned with ice water prior to preservation (Doxtater 1963). Field preservation

Table 1. Fishes Included in Lake Pontchartrain, LA, [illegible]

SPECIES	NO. ANALYZED	NO. WITH FOOD	MEAN SL, MM	MIN SL, MM	MAX SL, MM
Ictalurus punctatus	72	62	199.1	25.7	443.0
Ictalurus furcatus	138	112	234.9	29.5	428.0
Pylodictis olivaris	1	1	417.0	417.0	417.0
Bagre marinus	11	10	283.4	78.9	457.0
Arius felis	42	34	194.7	77.0	251.5
Micropterus salmoides	37	35	94.3	11.3	170.3
Lepomis punctatus	19	19	85.6	31.5	120.0
Lepomis microlophus	7	7	90.4	44.5	178.0
Lepomis macrochirus	16	15	88.9	39.0	143.0
Archosargus probatocephalus	14	6	245.7	73.9	382.0
Lagodon rhomboides	14	14	87.8	56.0	124.0
Pogonias cromis	11	2	461.9	54.0	620.0
Bairdiella chrysura	16	14	67.0	44.0	116.5
Cynoscion arenarius	143	109	102.2	55.0	404.0
Cynoscion nebulosus	50	32	198.3	37.0	443.0
Aplodinotus grunniens	4	4	261.5	230.0	274.0
Micropogonias undulatus	319	277	89.1	12.0	252.0
Leiostomus xanthurus	215	197	80.9	15.3	183.0
Sciaenops ocellata	21	19	142.3	51.1	455.0
Lepisosteus spatula	2	0	385.0	375.0	395.0
Lepisosteus oculatus	2	0	410.0	390.0	430.0
Lucania parva	60	37	30.9	17.7	246.8
Gambusia affinis	19	14	25.1	13.1	33.9
Fundulus grandis	103	84	55.8	17.8	96.9
Dorosoma cepedianum	1	1	128.0	128.0	128.0
Alosa chrysochloris	1	0	320.0	320.0	320.0
Gobiesox strumosus	34	34	37.1	19.9	60.9
Anchoa mitchilli	48	40	42.5	24.4	61.6
Membras martinica	13	4	79.2	71.0	87.9
Menidia beryllina	374	325	55.2	21.0	84.5
Gobionellus shufeldti	6	6	42.7	37.7	50.2
Microgobius gulosus	4	4	40.9	35.2	48.4
Gobiosoma bosci	69	53	29.7	15.0	47.5
Strongylura marina	39	34	174.3	68.0	475.0
Cyprinodon variegatus	43	39	95.1	29.1	359.0
Paralichthys lethostigma	11	6	229.3	102.0	355.0
Trinectes maculatus	110	69	52.4	14.7	83.5
Mugil cephalus	14	9	142.5	89.0	232.0
Fundulus similis	3	3	65.9	63.9	69.2
Carcharhinus leucas	2	1	856.5	791.0	922.0
Elops saurus	19	11	135.8	64.5	278.0
Poecilia latipinna	3	1	42.4	38.3	46.0
Polydactylus octonemus	3	3	113.0	107.0	119.0
Oligoplites saurus	2	1	55.0	40.5	69.5
TOTAL	2135	1748			

in 10% formalin was followed by water washing and final preservation in 40% isopropanol. Standard length in mm and weight in gm were recorded.

Stomach and intestinal contents were examined under a stereo microscope at 64-400 magnifications. Identifications were made to the most specific possible taxon,and counts of stomach or foregut items were computed. Weighted and unweighted frequencies and percentages for food taxa were tabulated (See Appendix).

DESCRIPTION OF STUDY AREA

Collecting sites were the regular nekton stations. Refer to Thompson and Verret, Chapter 12, for detailed descriptions.

RESULTS

I. Carcharhinidae

A. Carcharhinus leucas (Valenciennes). Bull Shark.

Odum (1971) reviewed food habit research on C. leucas. The bull shark is a nonspecialized carnivore that preys upon fishes, crabs, and shrimp. Six specimens from a south Florida estuary fed upon Arius felis, Penaeus duorarum, and Lophogobius cyprinoides. Darnell (1958) reported that 90% of the food of two bull sharks from Lake Pontchartrain consisted of fishes including Brevoortia patronus and Micropogonias undulatus. I examined two C. leucas. A small amount of well-digested fish remains was present in one stomach.

The bull shark is one of the few fishes in Lake Pontchartrain to actively prey upon other large, mobile fishes. On one occasion we witnessed a shark of approximately 1.2 m standard length (SL) attack and mutilate a similarly sized Polyodon spathula. The latter was struck and propelled violently across the surface by the shark. Upon retrieval,

the paddlefish was nominally alive but totally severed posterior of the anal fin. A clean, half-moon shaped bite 15 cm across was present on the flank. The incident was reminiscent of shark predation upon a Pogonias cromis described by Darnell (1958).

II. Lepisosteidae

A. Lepisosteus oculatus (Winchell). Spotted Gar.

The spotted gar is known as a lurking nonspecialized carnivore (Parker 1939, Bonham 1941, Gunter 1945, Lambou 1952, Hunt 1953). Fishes form the major food of adults, although some invertebrates are taken. Darnell (1958) briefly reviewed the literature and reported on seven spotted gar from Pontchartrain. Crabs (Callinectes sapidus) were 70% of the food; fishes comprised 24%. In the present study, two L. oculatus collected in November were analyzed. Neither contained food.

B. Lepisosteus spatula Lacepede. Alligator Gar.

According to Darnell (1958), the alligator gar has been characterized by previous researchers variously as a scavenger (Jordan 1905) and a predator (Wortman 1882, Hussakof 1914, Hildebrand and Towers 1927, Bonham 1941, Raney 1942, Gunter 1945, Lambou 1952). Prey ranges from fishes and crabs to birds. Darnell (op. cit.) examined "a large number" of L. spatula stomachs and reported heavy predation upon the blue crab (Callinectes sapidus) and the striped mullet (Mugil cephalus). Two alligator gar were examined in the present study. Neither contained food.

III. Elopidae

A. *Elops saurus* Linnaeus. Ladyfish, Ten-pounder.

Previous studies from Gulf of Mexico and Atlantic localities characterized *E. saurus* as predaceous upon penaeid shrimps and fishes (Linton 1904, Gunter 1945, McClane 1948, Knapp 1949, Reid 1954, 1955, Odum 1971). Gehringer (1959) observed cannibalism among young ladyfish under laboratory conditions. Darnell (1958) reported on five *E. saurus* from Lake Pontchartrain. Fishes such as *Anchoa mitchilli* comprised most of the food; penaeid shrimps were a small percentage. Sekavec (1974) analyzed 229 ladyfish from 18 Louisiana localities (three specimens from Lake Pontchartrain). Fishes (*Brevoortia patronus*, *Gambusia affinis*, and 11 other species) dominated the food. Six species of Decapoda were the only other important foods and occurred in small percentages.

Of 19 ladyfish examined in this study, 11 contained food. Mysids (*Mysidopsis almyra*) occurred in over 36% of the stomachs and comprised over 99% of the total food. No other fish in this study fed so predominantly upon one food taxon. Other recognizable foods were fishes (*Anchoa mitchilli*, *Menidia beryllina*, *Micropogonias undulatus*, *Poecilia latipinna* and others). Although fishes were less than 0.70% of the food by frequency, their relatively great bulk and presence in over half the stomachs demonstrate substantial piscivory by *E. saurus*.

IV. Belonidae

A. *Strongylura marina* (Walbaum). Atlantic Needlefish.

Atlantic needlefish are predators of fishes (*Mugil* spp., *Fundulus* spp., atherinids, clupeids) and shrimp (Hildebrand and Schroeder 1928, McClane 1948). Darnell (1958) examined seven *S. marina* from Lake

Pontchartrain. Small fishes such as Anchoa mitchilli were the main food, and adult insects were occasionally consumed.

I analyzed 39 needlefish from our regular Lake Pontchartrain sites; 34 contained food. My results are comparable to those reported by Darnell with the exception of Chironomidae larvae (Insecta: Diptera) and pupae, not reported by Darnell, in guts of several needlefish. Mean standard length of needlefish was 174 mm; smaller S. marina had a broader diet (300-plus mm); larger specimens are primarily piscivorous. Fishes occurred in over 41% of the guts and were 24.5% of the total food. Anchoa mitchilli was the only identifiable prey fish. Insecta comprised 42% of the total food. In addition to Chironomidae larvae, adult Odonata, corixid Hemiptera, and terrestrial Hymenoptera (ants) entered the food. Crustacea were nearly 30% of the total food but were consumed by relatively few needlefish. Most of the crustacean portion of the diet was the amphipod Corophium lacustre. Nereid polychaetes were present in small amounts (the tendency of polychaetes and other worms to be digested rapidly leads to their frequent underestimation in food studies).

B. Diel Study

In August 1978, 29 Strongylura marina ranging in size from 169.0-410.0 mm SL were dipnetted from the Inner Harbor Navigation Canal (IHNC) at 2200 hrs, 0000 hrs, 0300 hrs, and 0400 hrs. The needlefish were observed actively feeding at the surface. Tidal speed for each time period was measured with an Endeco current meter. Flow was ebbing throughout the study period. Foods in the foregut were considered indicative of recent feeding. Over 31% of the needlefish fed upon

fishes (all recognizable remains were Anchoa mitchilli), and over 24% consumed insects. The insects fed upon were exclusively terrestrial. Other foods were not abundant. Large numbers of Membras martinica were feeding "side by side" with the needlefish. Although the Membras sp. were of similar size to anchovies later found in the needlefish guts, no predation upon them was observed.

Heaviest feeding occurred between 2200 hrs and midnight. Predawn feeding was sporadic and light (Fig. 1). As shown in Figure 1, feeding rate bore some relation to rate of tidal flow. Reduction of current speed presumably reduced the rate at which food was made available to the needlefish. Abundance of terrestrial insects in the needlefish diet further demonstrated opportunistic feeding.

V. Engraulidae

A. Anchoa mitchilli (Valenciennes). Bay Anchovy.

Qualitative studies (Hildebrand and Schroeder 1928, Reid 1954, McClane 1955, Springer and Woodburn 1960, Van Engel and Joseph 1968, Diener et al. 1974) described the bay anchovy as predaceous upon small crustaceans. Mollusks, fishes, and other foods entered the diet incidentally. Quantitative work (Odum 1971, Carr and Adams 1973) demonstrated feeding progression with respect to size and type of prey. Anchovies fed selectively from larval stages onward. Darnell (1958) reported similar foods from 92 Lake Pontchartrain A. mitchilli and described two primary feeding states: "young" individuals straining zooplankton throughout the water column and selective predation upon small shrimps and fishes by older anchovies. Detritus was noted as a possible "nutritional supplement" during both stages.

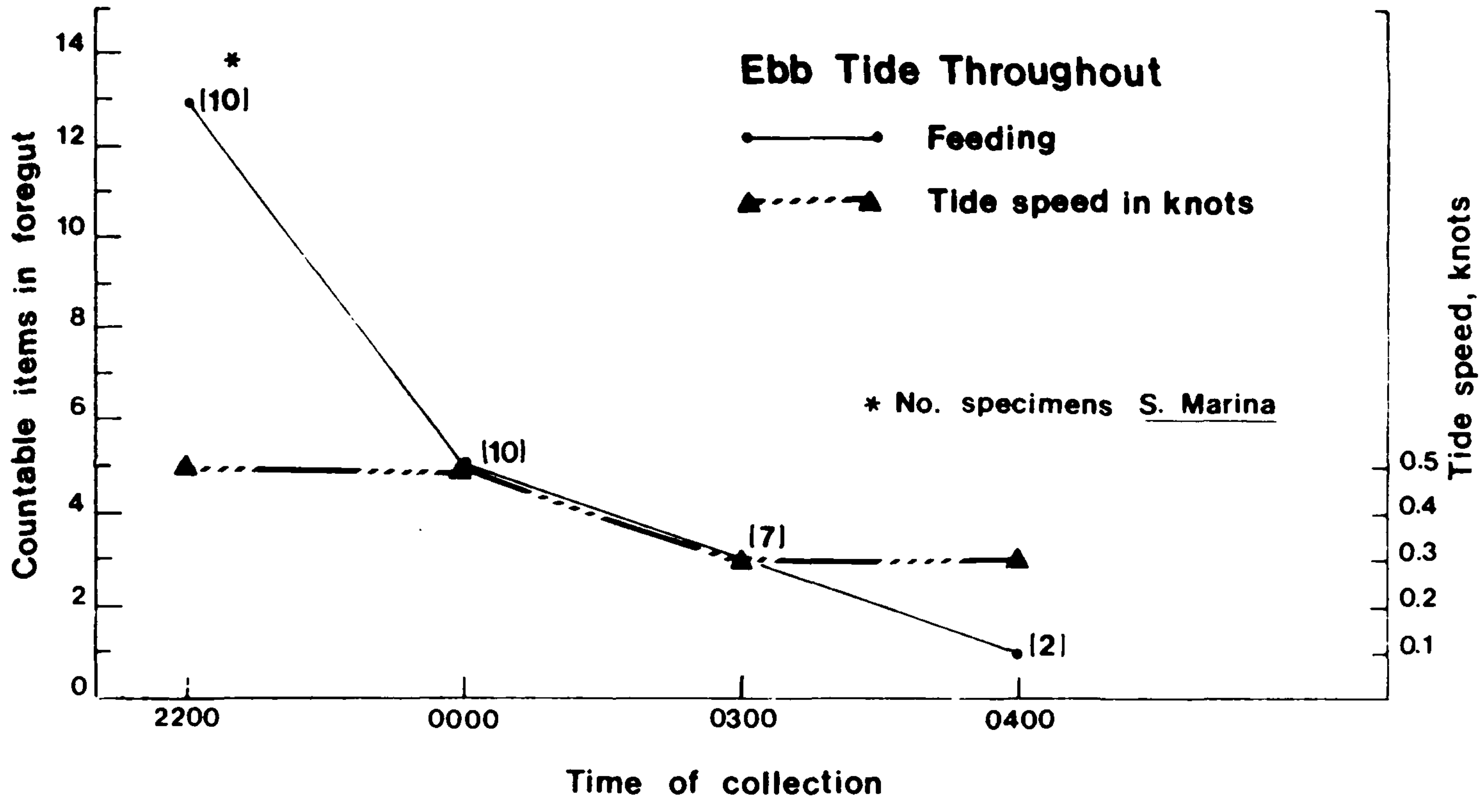

Figure 1. Feeding, time, and tidal flow viewed simultaneously for _Strongylura marina_ dipnetted from Inner Harbor Navigation Canal, Lake Pontchartrain, LA, during August 1978.

In the present study, 48 A. mitchilli were examined. Forty contained food. The polychaete Laeonereis culveri was 16% of the total food, but it was all in the gut of one anchovy. Other important foods included small bivalve remains (25% total food, present in 40% of fish) and Copepoda (48% total food, present in over 50% of fish). Incidental items such as Amphipoda, Hemiptera, and Diptera also occurred. The mysid Mysidopsis almyra was 6% of the total food and was in 18% of the stomachs.

For comparison with Darnell (1958), I grouped anchovies with food by size class (Fig. 2). No progressive trends emerged, due possibly to too few data. Two points were discernible: more mobile foods (Mysidacea) did not appear in the food until 38-44 mm, a medium size class. Secondly, the frequency of "incidental" items increased slightly with growth. With increasing size, A. mitchilli apparently becomes a more adept and wider-range feeder.

Differences in food and feeding were clear when anchovies were grouped by station (Fig. 3). All collections discussed were trawls. Off the Tchefuncte River mouth, juvenile Bivalvia made up 90% of the total food and were fed upon by all fish in the sample. Insects, copepods, and mysids were a relatively small component of the diet. Feeding in this group of anchovies was done on and near the bottom. Sand was present in several stomachs. Darnell (1958) noted some bivalve consumption in A. mitchilli, but not to the degree I found in my samples. Near The Rigolets, Copepoda were the predominant food: 84% of the anchovies examined contained copepods. Bivalves, mysids, and oligochaetes were of minor importance. The most diverse diet was observed from a trawl collection made off the mouth of Chef Menteur Pass. Amphipoda and Copepoda

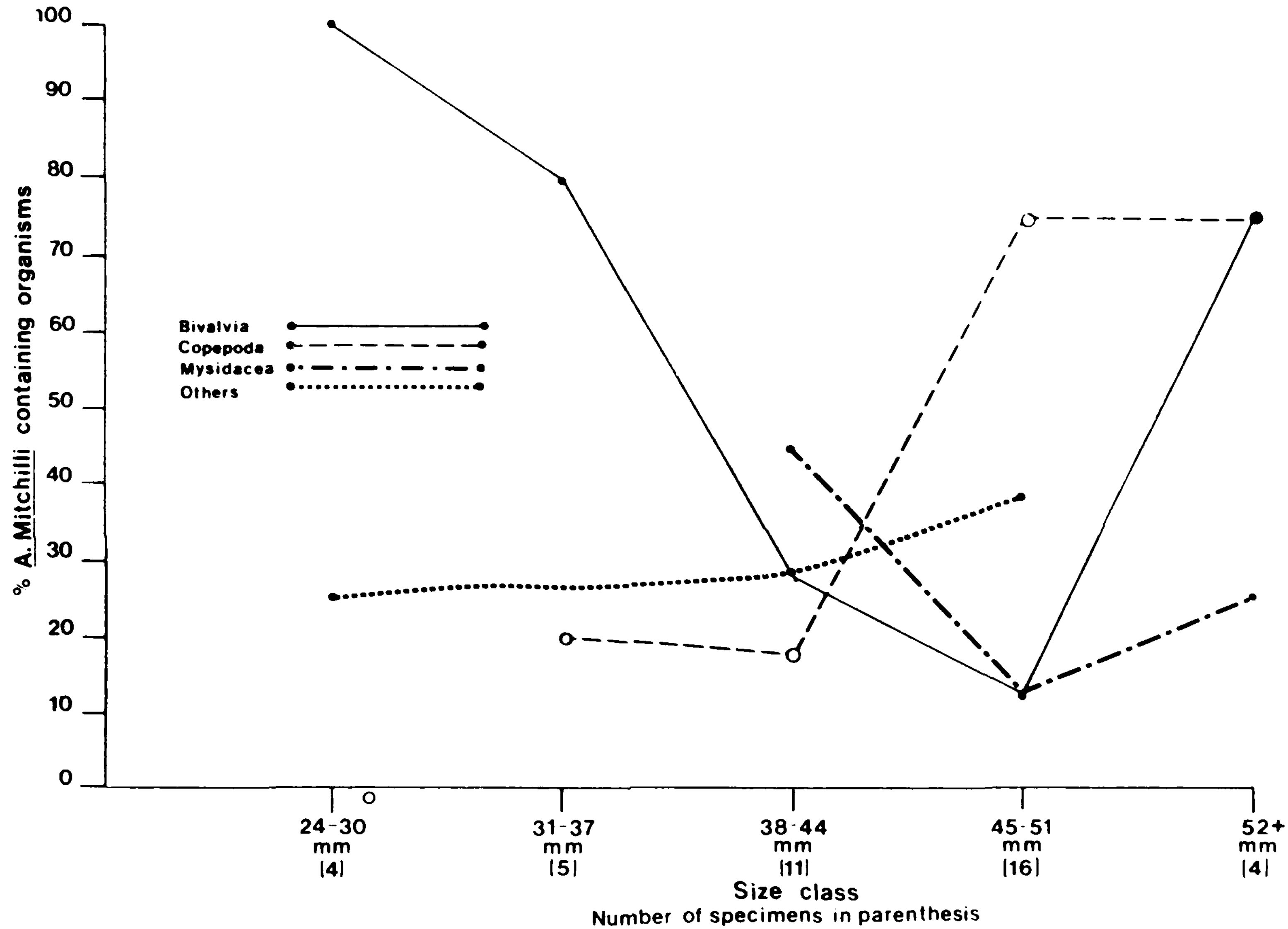

Figure 2. Growth-related feeding changes in Anchoa mitchilli from Lake Pontchartrain, LA, 1977-1978.

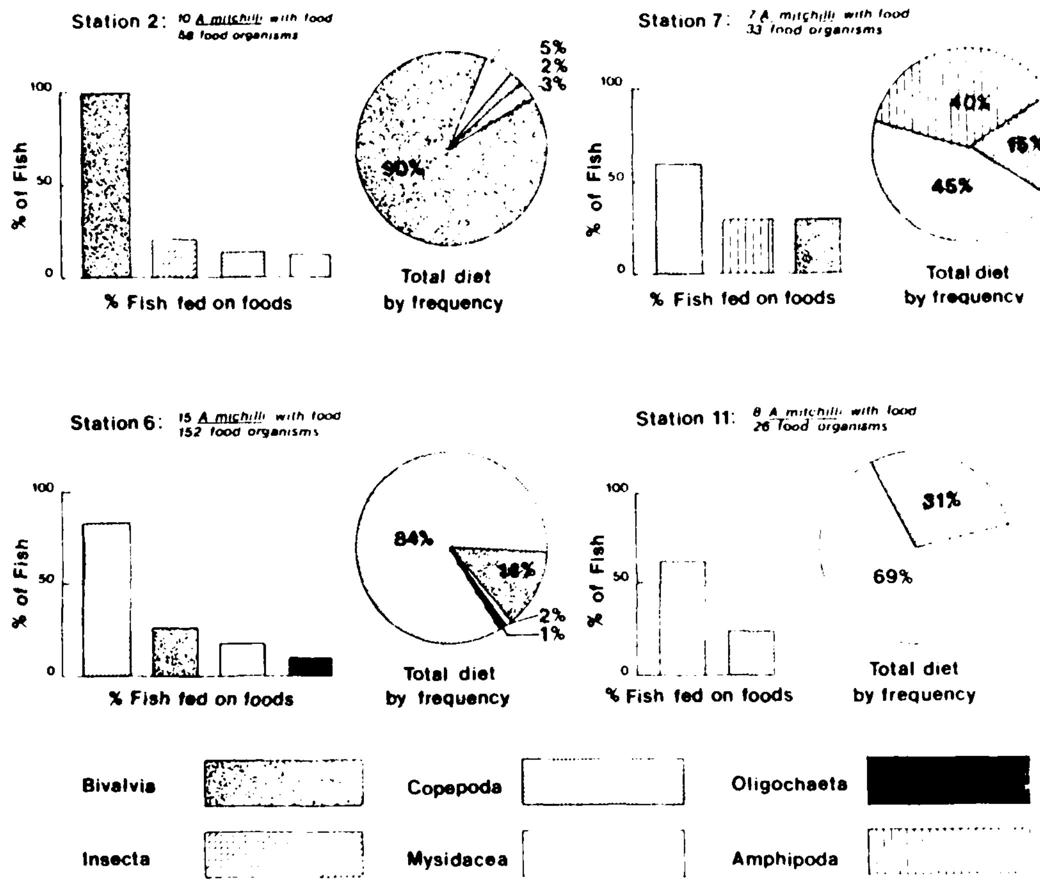

Figure 3A. Geographic variation in feeding among Anchoa mitchilli from Lake Pontchartrain, LA, 1977-1978.

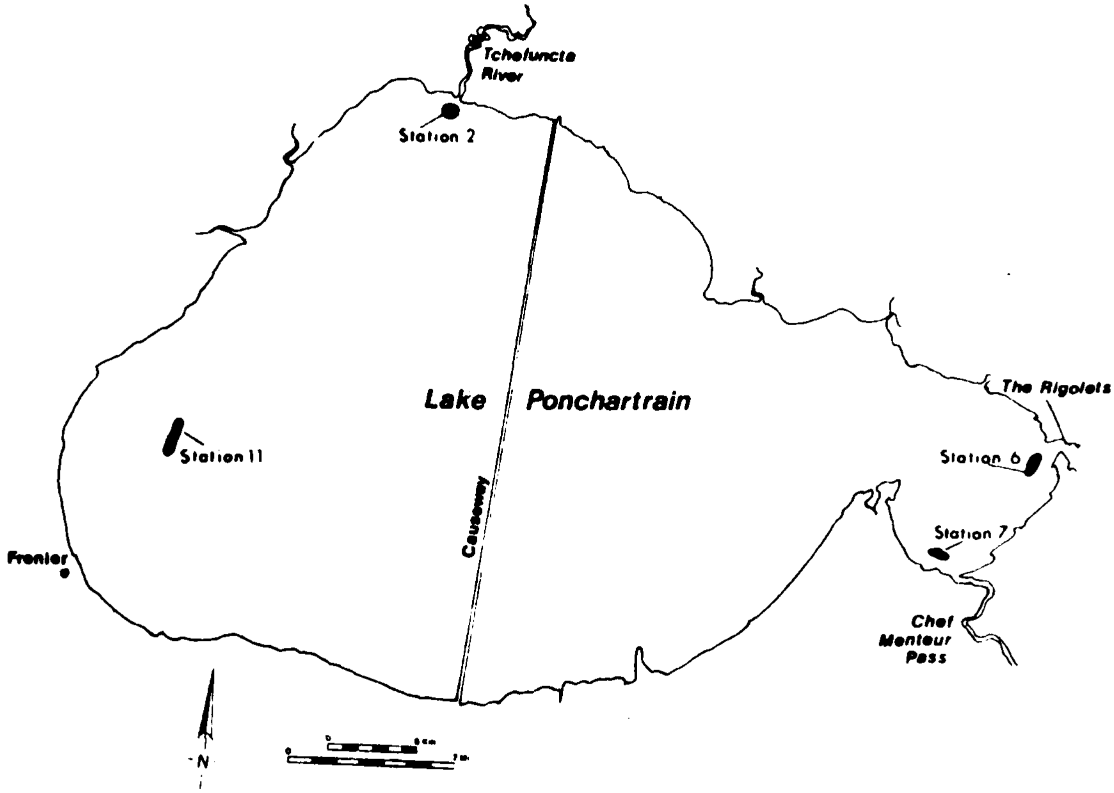

Figure 3B. Geographic variation in feeding among Anchoa mitchilli from Lake Pontchartrain, LA, 1977-1978.

each comprised nearly half of the total food. Bivalvia were 15% of the total. Fifty-seven percent of the anchovies from this group consumed Copepoda, and 29% of the stomachs contained amphipods and bivalves. *A. mitchilli* from the west side of Lake Pontchartrain consumed Mysidacea heavily: 69% of the total food was mysids. Copepoda comprised the remaining 31%.

My small sample size did not allow speculation upon the wide differences in diet from location to location in Lake Pontchartrain. Anchovies were the most common species collected during our nekton survey (Thompson and Verret, Chapter 12); their ubiquity probably necessitated opportunism in feeding rather than the "selectivity" noted by Darnell (1958). Differences in diet noted here were probably due to feeding on whichever invertebrates were most abundant.

VI. Sciaenidae

A. *Sciaenops ocellata* (Linnaeus). Red Drum, Redfish.

Small redfish (30-200 mm SL) have been characterized as feeding upon small crustaceans. Larger *S. ocellata* prey primarily upon penaeid shrimp, blue crabs (*Callinectes sapidus*), and fishes (Linton 1904, Hildebrand and Schroeder 1928, Pearson 1929, Gunter 1945, Knapp 1949, Reid 1955, Boothby 1969, Fontenot and Rogillio 1970, Odum 1971). Diener et al. (1974) reported that over 25% of 51 redfish (38-533 mm SL) from Clear Lake, Texas, consumed nematoda and the Gulf menhaden. Twelve redfish (184-625 mm) from Lake Pontchartrain fed predominately upon *Callinectes sapidus* and *Rhithropanopeus harrisii* (Darnell 1958).

In the present study, 19 redfish with food were examined. As shown in Figure 4, Amphipoda and fishes were present, respectively, in 34% of

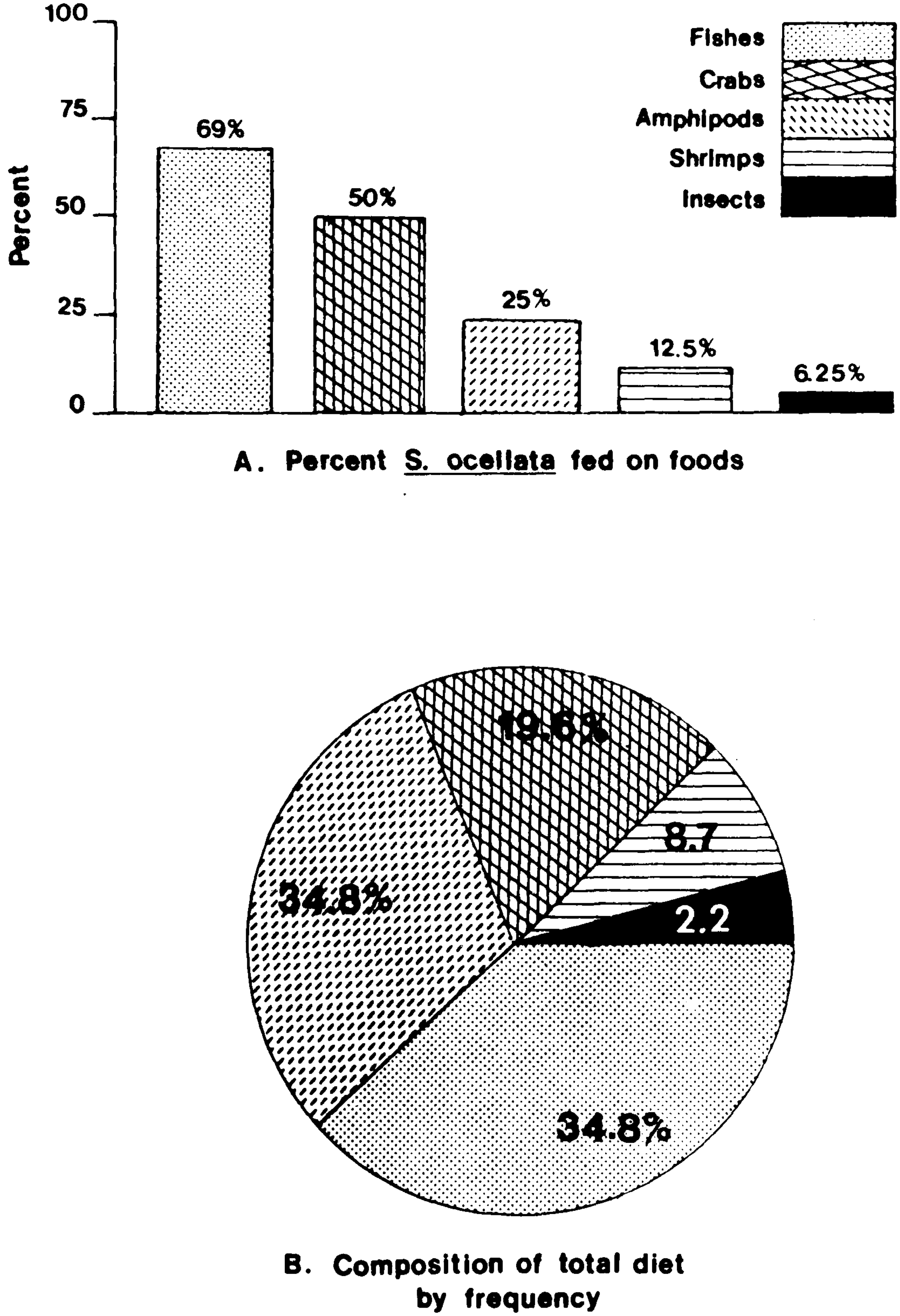

Figure 4. Percent of fish that consumed each food taxon (A) and percent frequency of the foods (B) among *Sciaenops ocellata* from Lake Pontchartrain, LA, 1977-1978.

the stomachs. Crabs (Callinectes sapidus, Rhithropanopeus harrisii), shrimp (Macrobrachium ohione, Palaemonetes spp.), and insect remains occurred with lesser, descending abundance. Fishes and crabs were the bulk of the total food by frequency. These results agree well with the conclusions of Darnell (op. cit.). Darnell also noted heavy reliance upon blue crabs and fishes.

B. Aplodinotus grunniens Rafinesque. Freshwater Drum.

Darnell (1958) reviewed previous food literature on the freshwater drum. The species in fresh water progresses with growth from a diet of small crustaceans to aquatic insects to larger mollusks, decapods, and other foods. Darnell examined four A. grunniens from Lake Pontchartrain with food and reported the bivalves Congeria leucophaeta and Rangia cuneata as major foods. He stated "the food of this species appears to be quite similar to that of the young black drum".

In the present study, four freshwater drum (230-274 mm) were analyzed. Gammarus spp. amphipods (32.70%), Palaemonetes spp. shrimp (33.65%), and fishes (28.85%) were major foods. All four drum had eaten amphipoda and fishes. These A. grunniens were collected from marsh and open-lake areas in the southwest corner of Lake Pontchartrain. The small sample size limits discussion; but the disparity between these findings and those of Darnell (op. cit.) is clear. The freshwater drum should not be fitted trophically with the young black drum (Pogonias cromis); I believe the former to be a facultative predator capable of existing upon mollusks and insects, or shrimps and fishes, or a combination of foods. In Lake Pontchartrain, the freshwater drum ranges between main-lake and marsh areas. Its diet varies according to feeding location. Pogonias cromis seems less flexible in its food requirements.

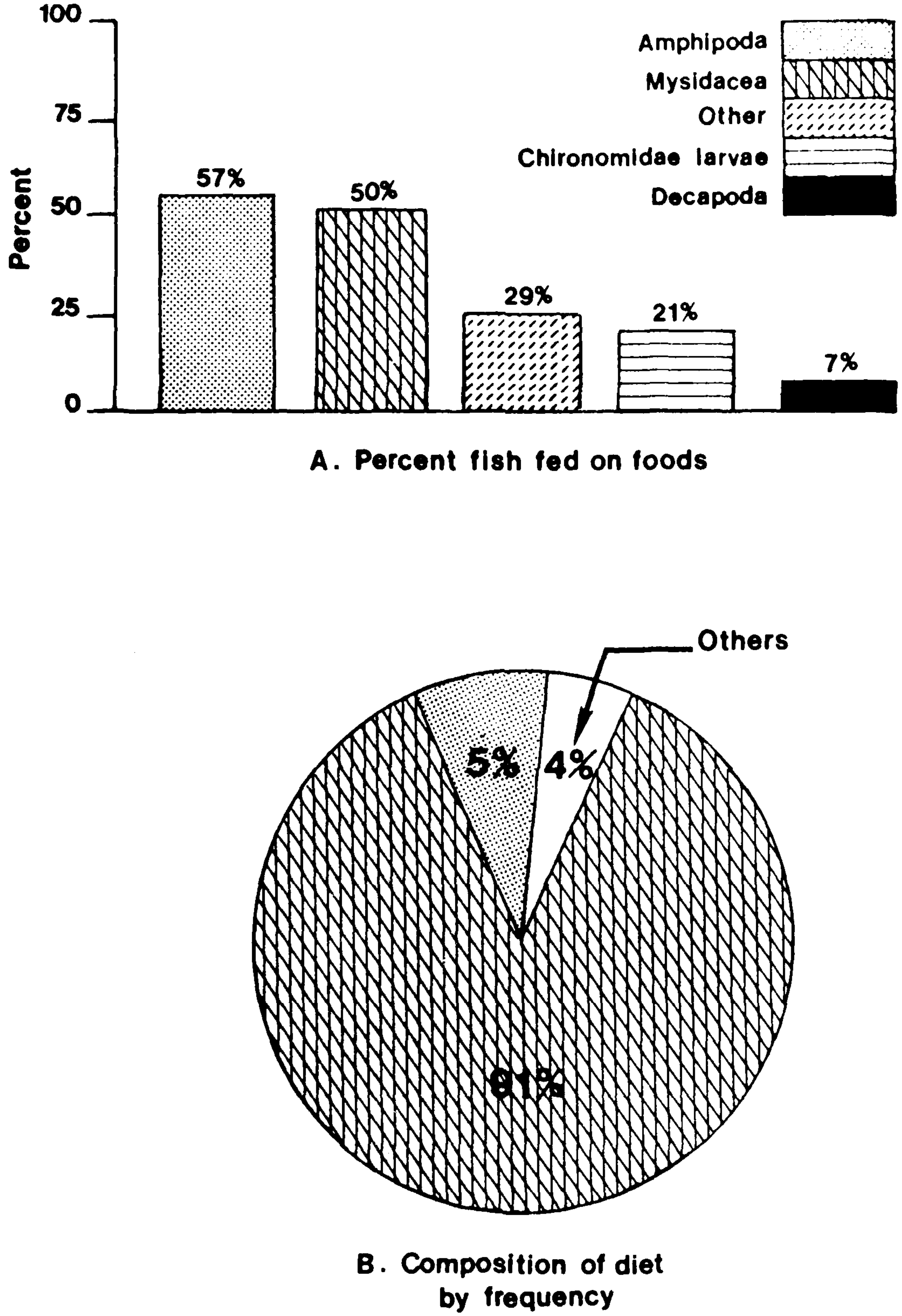

Figure 5. Percent of fish that consumed each food taxon (A) and percent frequency of the foods (B) among Bairdiella chrysura from Lake Pontchartrain, LA, 1977-1978.

C. *Bairdiella chrysura* (Lacepede). Silver Perch.

Previous research on the silver perch indicates that smaller individuals (40 mm) feed mainly upon copepods and other crustaceans; with growth, larger crustaceans and fishes assume greater importance (Linton 1904, Welsh and Breder 1923, Hildebrand and Cable 1930, Reid 1954, Reid et al. 1956, Van Engel and Joseph 1968, Odum 1971, Thomas 1971, Carr and Adams 1973, Stickney et al. 1975, Chao and Musick 1977). Darnell (1958) examined 20 Lake Pontchartrain *B. chrysura* (70-143 mm) with food. He recognized four primary food types: small crustaceans, larger penaeid and palaemonid shrimp, fishes, and "miscellaneous material".

I analyzed 14 silver perch with food (44-116.5 mm SL). As shown in Figure 6, Amphipoda (Corophium spp., Gammarus spp.) and the mysid *Mysidopsis almyra* dominated the food. Other organisms such as nereid worms, shrimp, and isopods were fed upon lightly. Unidentified remains of one fish were noted. Darnell (op. cit.) also reported substantial feeding upon Mysidacea. His sample of *B. chrysura* contained larger individuals than mine; fishes and shrimp undoubtedly gain importance and partially replace mysids in the diets of the older perch. Also, my collections were made in North Shore grassbeds, where mysids and amphipods are common during summer. In grassbed habitats, numbers and vulnerability of such organisms may extend the small crustacean feeding stage for *B. chrysura* and other predatory fishes.

D. *Cynoscion arenarius* Ginsburg. Sand Seatrout.

Cynoscion arenarius passes through two major feeding stages. Below approximately 60 mm SL, small crustaceans such as copepods and mysids are primary foods. With growth, fishes and macrocrustaceans dominate the

diet, although piscivory begins at roughly 40 mm (Reid 1954, 1955, 1956, Diener et al. 1974). Darnell (1958) examined 47 C. arenarius (40-225 mm) with food from Lake Pontchartrain. He reported smaller specimens (40-149) mm fed upon mysids and fishes. Small invertebrates were absent from the diet of trout 150 mm or larger. Larger trout consumed penaeid shrimp and fishes.

In the present study, 100 C. arenarius (55-404 mm) with food were analyzed. Results of the analysis were decidedly split between two food taxa: Mysidacea and Pisces. The above were 95% and 4.5% of the total food by frequency (Fig. 6). Over 60% of the trout stomachs contained mysids (primarily Mysidopsis almyra), and over 50% contained fishes (Anchoa mitchilli, Myrophis punctatus, Elops saurus, Membras martinica, and numerous unidentifiables). Other foods such as Amphipoda were infrequently taken and numerically few.

Frequencies of the two major food taxa plotted against size classes of trout with food clearly show progressively different feeding (Fig. 7). The two smallest size classes consumed mysids, but fishes did not enter the diet until the 66-75 mm class. Thereafter, the proportion of fishes in the food increased rapidly as mysids gradually decreased. Differences in rate of change were greater than apparent from the graph alone due to the much greater volume of fishes compared to mysids. These size trends are difficult to compare with those of Darnell (op. cit.) because he lumped the most critical few size classes into one 40-99 mm class. The data do compare well overall, however. Sheridan (1978, unpubl.) found similar progression in C. arenarius from Appalachicola Bay: Mysidacea (in this case mainly Mysidopsis bahia) and other microcrustaceans decreased in importance with growth. A rapid switch to piscivory was concurrent with growth.

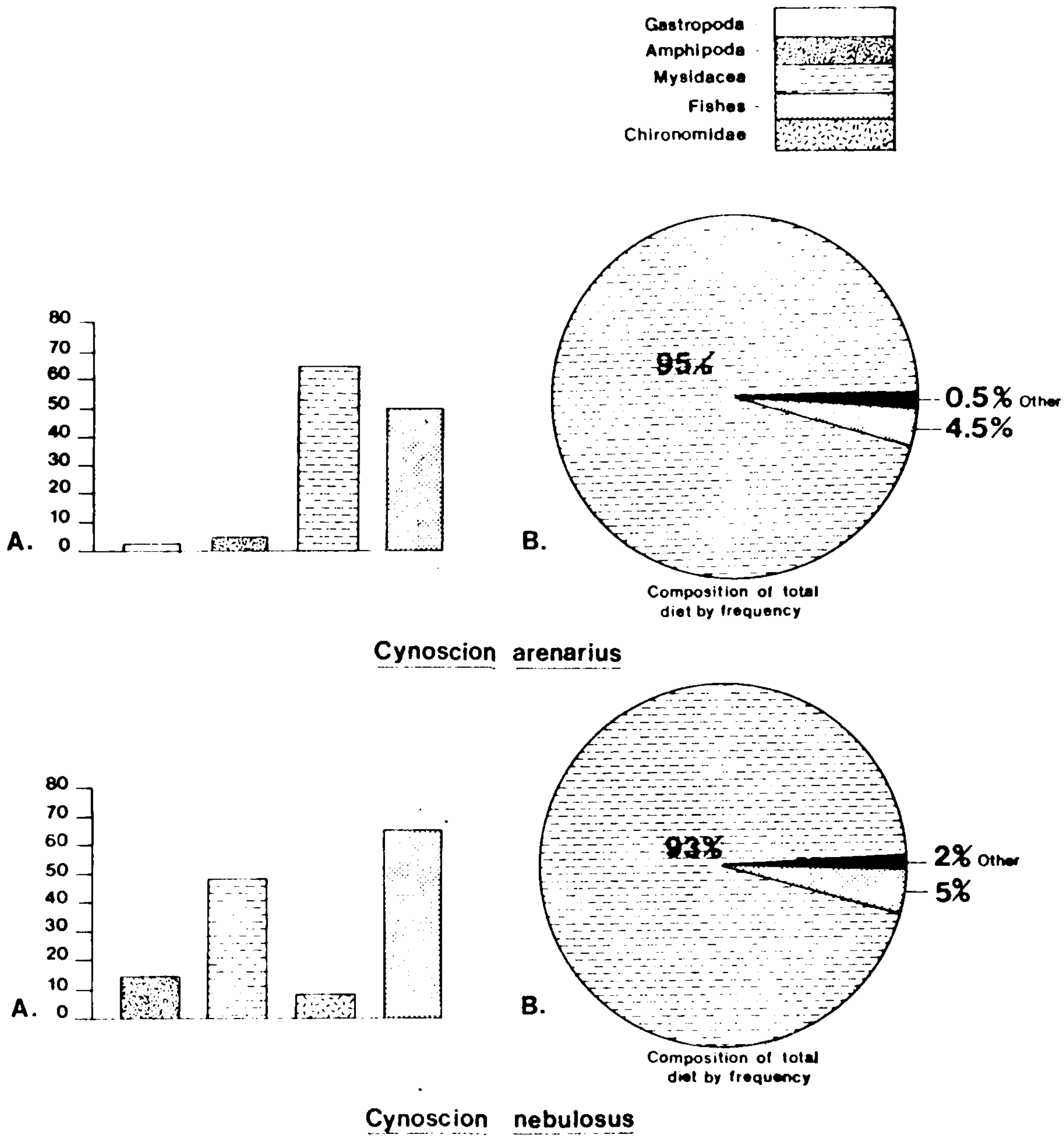

Figure 6. Percent of fish that consumed each food taxon (A) and percent frequency of the foods (B) among *Cynoscion arenarius* and *Cynoscion nebulosus* from Lake Pontchartrain, LA, 1977-1978.

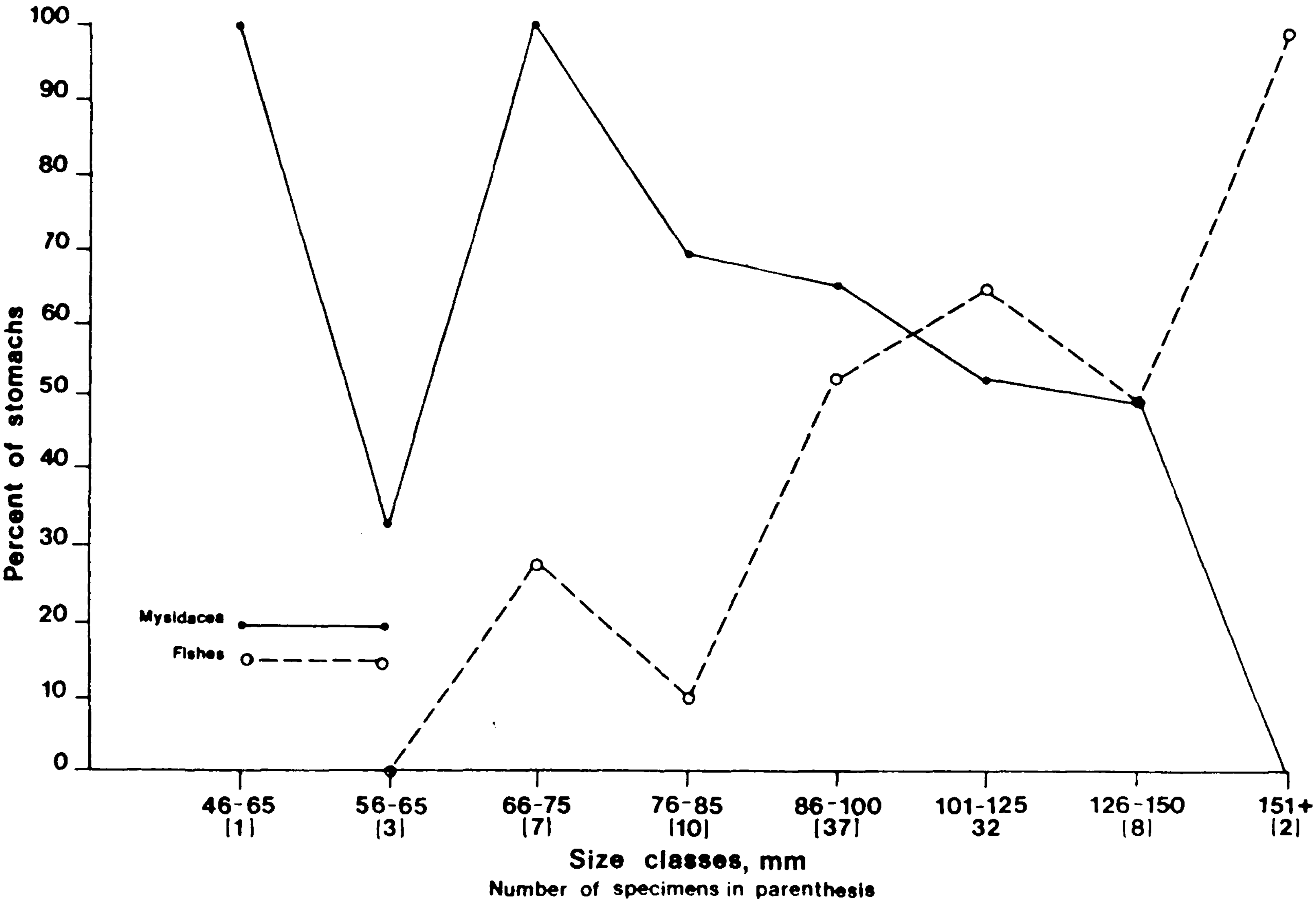

Figure 7. Growth-related feeding changes in Cynoscion arenarius from Lake Pontchartrain, LA, in 1977-1978.

E. Cynoscion nebulosus (Cuvier). Spotted Seatrout.

Previous research has described Cynoscion nebulosus as a semispecialized predator passing through up to four distinct feeding stages from microcrustaceans through fishes and penaeid shrimp (Linton 1904, Hildebrand and Schroeder 1928, Gunter 1945, Knapp 1949, Moody 1950, Reid 1954, Fontenot and Rogillio 1970, Odum 1971, Stewart 1961, Tabb 1961, Lorio and Schaefer 1966, Diener et al. 1974). Food selection followed seasonal changes in prey abundance. Carr and Adams (1973) made a thorough literature survey and reported on the food of 174 juvenile C. nebulosus (divided into 16 size classes) from estuarine grassbeds near Crystal River, Florida. Two major food groups were reported: fishes/larger shrimp and fishes/small shrimp/mysids. Utilization of fishes by smaller C. nebulosus (20-45 mm SL) was higher than observed elsewhere.

Darnell (1958) examined 58 trout (37-443 mm) with food from Lake Pontchartrain. His results were in line with previous findings from other areas except for a "jump" to heavy piscivory at 100 mm instead of 150 mm as reported by Moody (op. cit.). A seasonal lack of penaeid shrimp was stated as cause.

I analyzed 50 C. nebulosus (37-443 mm), of which 32 contained food. As shown in Figure 6, Mysidacea (mainly Mysidopsis almyra) were 93% of the total food and Pisces were 5% of the total. Mysids occurred in nearly 50% of the stomachs and fishes, in over 70%. Recognizable fishes in the food were Brevoortia patronus, Micropogonias undulatus, Gobiosoma bosci, Dorosoma spp., and Mugil cephalus. Other foods (Amphipoda, Chironomidae larvae) were of minor importance.

Progression in feeding with growth was striking and similar to that demonstrated in _C. arenarius_ (see preceding section). Figure 8 shows that the smallest trout fed heavily upon Mysidacea, moderately upon Amphipoda, and lightly upon Pisces. With growth, amphipods dropped gradually from the food, mysids decreased rapidly, and fishes quickly assumed primary importance. The largest trout did not eat mysids.

Food habits of seatrouts in the Lake Pontchartrain system overlap. Major foods of _C. arenarius_ and _C. nebulosus_ were ubiquitous throughout the course of our study. _Mysidopsis almyra_ is considered by some researchers to be the single most important fish food organism in the mid-Gulf estuarine zone (Heard 1979, pers. comm.). Forage fishes such as _Anchoa mitchilli_ are among the most common fishes in Lake Pontchartrain (Thompson and Verret, Chapter 12). Abundance of the above two taxa was apparently high enough to allow both trouts to feed nearly exclusively upon them. Great abundance of prey species tends to allow overlapping feeding niches, just as prey scarcity can result in trophic segregation (Tyler 1972, Ross 1977). _Cynoscion_ spp. were abundant in Lake Pontchartrain during 1978; and the two closely related species, similar in feeding habits, could overlap.

With respect to juvenile trouts, segregation by habitat resulted in differences in feeding niches. We took young _Cynoscion arenarius_ almost exclusively by trawling in deeper, open lake areas. Young _C. nebulosus_, however, were alway associated with beds of aquatic vegetation along the shoreline and in marshes. Water depths were less than two meters. Thompson and Verret (Chapter 12) reported syntopic occurrence of the two trouts just once in nearly 400 collections that included one or the other _Cynoscion_ spp. Whether the segregation in habitat among young trout is

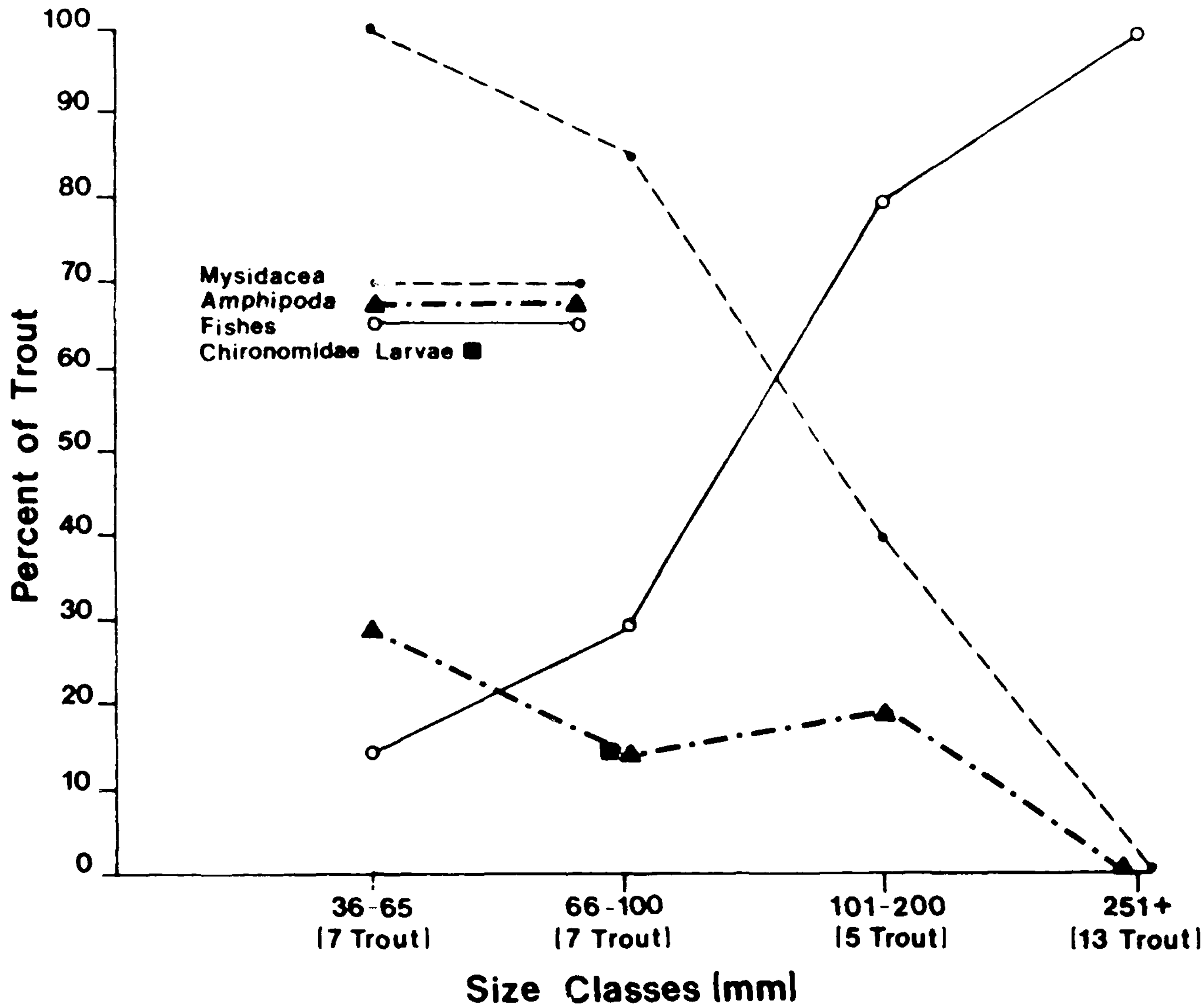

Figure 8. Growth-related feeding changes in Cynoscion nebulosus from Lake Pontchartrain, LA, in 1977-1978.

primarily a water depth relation is not presently known. Ross (1977) has stated that spatial segregation related to water depth is often important to resource partitioning.

Examination of incidental foods of C. nebulosus revealed grassbed and marsh organisms. The mysid Taphromysis louisianae is generally found in salinities less than one part per thousand and was especially abundant in inshore marsh and grass areas near Lacombe (North Shore) and the mouth of Bayou St. John (South Shore). Both trouts fed upon T. louisianae, but incidence in C. nebulosus greatly exceeded that in C. arenarius, (both by percentage and number counted). Gobiosoma bosci, a common grassbed fish, was fed upon by C. nebulosus but not by C. arenarius. Trophic segregation among young spotted seatrout and sand seatrout was either a result of habitat segregation or an evolved divergence due to several factors including feeding.

Darnell (1958) downplayed the "grassbeds" of Lake Pontchartrain and their importance in the ecology of the system. He stated "actually, the food of the young and adult spotted seatrout indicated that in Lake Pontchartrain, neither is critically associated with shallow grassy areas" and reported a "virtual absence of weed beds." These statements are untrue in the present ecology of the lake and probably were untrue in 1958. Areas of submerged aquatic vegetation are clearly important nursery grounds for young Cynoscion nebulosus.

F. Micropogonias undulatus (Linnaeus). Atlantic Croaker.

Feeding in the croaker has been studied by Linton (1904), Smith (1907), Welsh and Breder (1923), Hildebrand and Schroeder (1928), Pearson (1929), Hildebrand and Cable (1930), Gunter (1945), McClane (1948),

Roelofs (1954), Reid (1955), Reid et al. (1956), Van Engel and Joseph (1968), Hansen (1969), Thomas (1971), Stickney et al. (1975), and Chao and Musick (1977). M. undulatus is a generalized feeder on and near the bottom. Young croakers feed upon zooplankton, microcrustaceans, and small mollusks. Adults consume annelids, polychaetes, mollusks, decapods, and fishes. Feeding becomes more generalized with growth. Darnell (1958) analyzed 161 M. undulatus (10.0-325.0 mm) from Lake Pontchartrain. He observed four overlapping but distinct food stages: zooplankton, "micro-bottom" animals, detritus, and larger organisms of several types. Feeding was more diverse with growth. Some potential overlap with spot (Leiostomus xanthurus) was noted. Both species actively dig into the substrate when feeding. However, a specific study of feeding behavior as related to body form showed that L. xanthurus feeds "into" the substrate more than M. undulatus, thus establishing feeding niche segregation (Chao and Musick 1977).

In the present study, 277 croakers (12-252 mm) with food were examined. As shown in Figure 9, the diet was quite diverse. Mysidacea (primarily M. almyra) were the most frequently eaten organisms. Nearly 40% of the stomachs analyzed contained mysids, and 20% of the total food was Mysidacea. Bivalvia such as Rangia cuneata, Congeria leucophaeta, and Macoma mitchilli occurred in nearly 35% of the stomachs and comprised roughly 8% of the total food. Chironomidae larvae (Insecta) also occurred in almost 35% of the guts and comprised slightly over 9% of the total food. Amphipoda (Corophium lacustre, Gammarus tigrinus, Grandidierella bonneroides, and unidentifiables) were approximately 9% of the total food and were eaten by nearly 30% of the croakers. Calanoid and other copepods comprised over 46% of the total food by frequency and

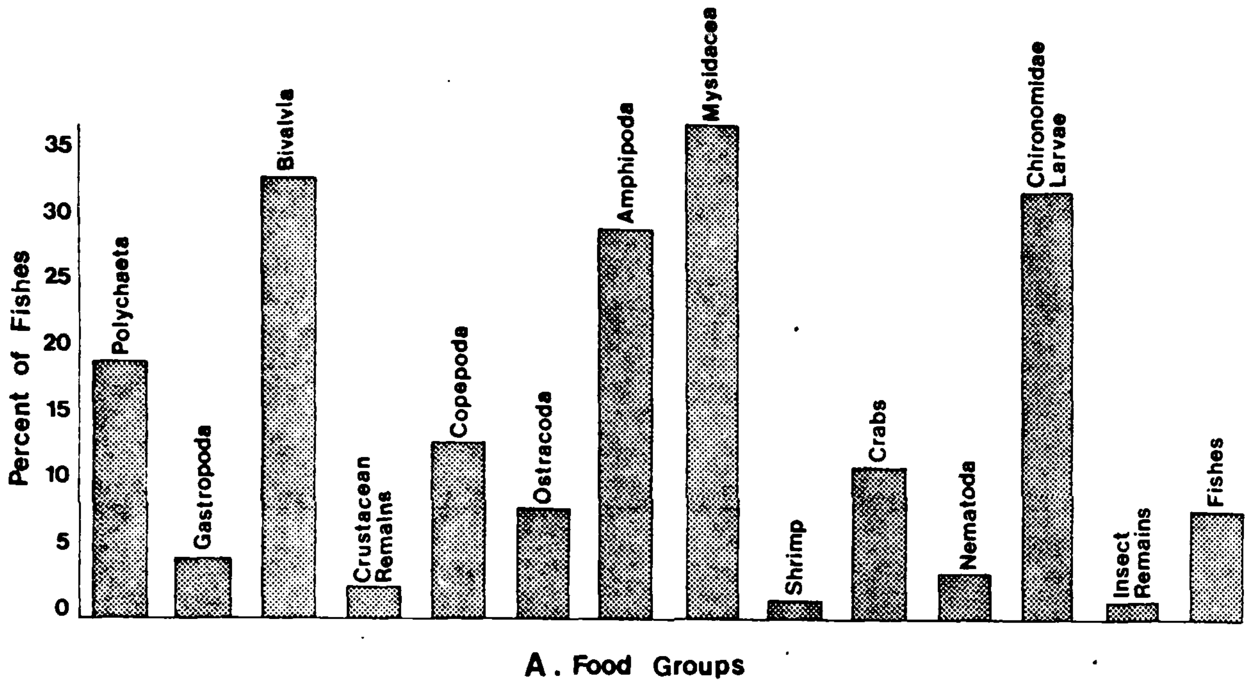

Figure 9A. Percent of fish that consumed each food taxon among *Micropogonias undulatus* from Lake Pontchartrain, LA, 1977-1978.

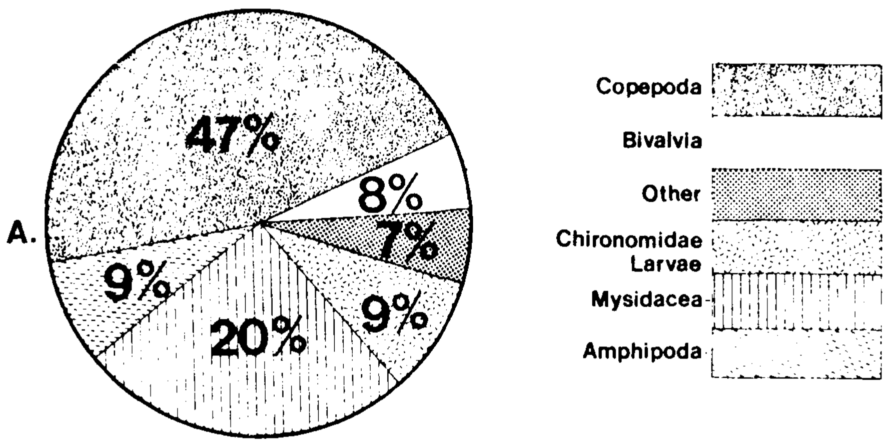

Figure 9B. Percent frequency of foods among <u>Micropogonias undulatus</u> from Lake Pontchartrain, LA, 1977-1978.

were present in nearly 15% of the stomachs. Polychaetes were consumed by more than 19% of the croakers. Their portion of the total diet was less than 2%, but previously mentioned problems with swift digestion and fragmentation of these animals probably limited efficacy of my analyses. Sheridan (1978, unpublished) termed polychaetes "the basis" of the croaker diet in the Appalachicola estuary. Crabs (primarily Rhithropanopeus harrisii) occurred in over 10% of the croakers and were less than 2% of the total food. Fishes (Anchoa mitchilli and unidentifiables) were in about 8% of the guts and comprised less than 1% of the total food. Their relatively large bulk as food compensated to some degree for infrequency in the diet. As made obvious by Figure 10, diversity of the croaker diet was very great. Four taxa occurred in 30% or more of the stomachs and three more, in 10% or greater. Most organisms in the food fit previous researchers' results: feeding in the main occurred near, on, and in the substrate.

As demonstrated in Figure 10, croakers of smaller size classes fed heavily upon Copepoda and Amphipoda. With growth, the diet became more diverse (this was also observed by Darnell [op. cit.]). A break point was evident between 56-75 mm. Here copepods and amphipods decreased rapidly as Bivalvia, Mysidacea, and Chironomidae larvae increased. From the above-mentioned size class on, feeding was increasingly predation upon discrete, motile organisms such as crabs and fishes. Feeding trends were clear in the largest size class. Bivalves dropped to low levels, as did Chironomidae larvae. Copepods and amphipods dropped completely from the food. Crabs (which did not enter the food until 76 mm was attained), mysids, and fishes were main foods of larger croakers. As reported by Darnell (op. cit.), food variety decreased somewhat with growth. I observed a drop in Bivalvia with growth not seen by Darnell. Fishes were

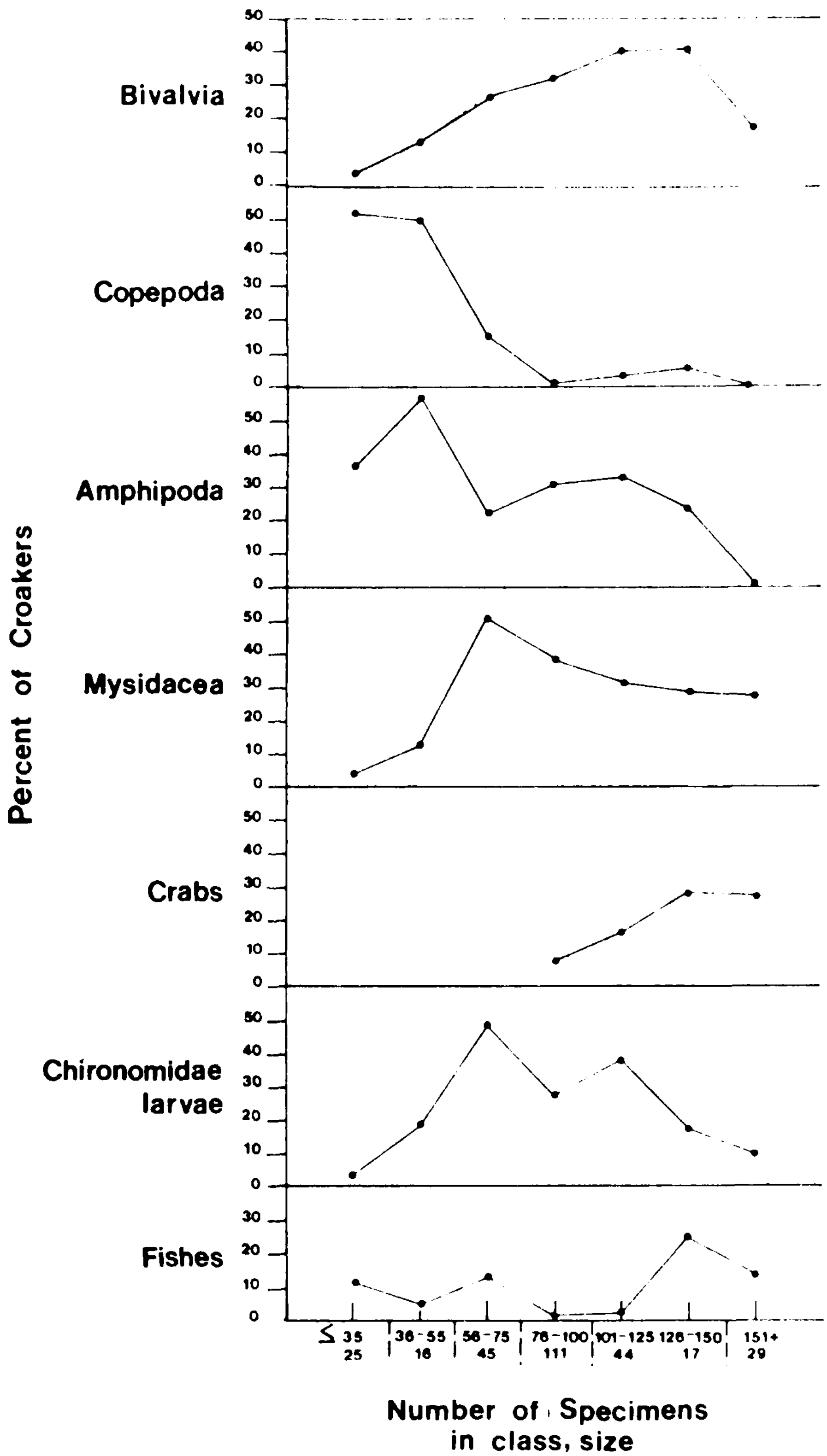

Figure 10. Growth-related feeding changes among *Micropogonias undulatus* from Lake Pontchartrain, LA, 1977-1978.

infrequent and irregular but were eaten from the smallest size class on and increased substantially in the largest classes. Although some 23% of the guts contained amorphous material and detritus, I would consider the material a consequence of the croakers' tendency to dig into substrates rather than the "important food category" claimed by Darnell (op. cit.). Sheridan (1978, unpublished), it should be mentioned, reported heavy detritus content in guts of several size classes of croakers from Appalachicola Bay. He did not, however, ascribe special importance to the detrital component. Chao and Musick (1977), in a study of the York River estuary, did not consider detritus an important food.

Station-by-station comparison of croaker food was limited to those stations from which mean standard lengths of analyzed fish were similar, since diet and growth were so strongly related.

Three habitat types were labeled by lumping collecting stations in an attempt to compare similarities in biophysical habitat with foods of croaker. Efficacy of this analysis was limited by moderate disparity in size of the croakers analyzed. Comparisons are set up, located, and graphed in Figure 11. Croakers from near the mouths of the Tangipahoa and Tchefuncte Rivers differed from specimens analyzed elsewhere mainly by the presence of a few hemipteran insects and the relative paucity of bivalves. Available foods in river mouth areas would vary greatly according to factors such as river discharge. High discharge periods would increase variety and abundance of foods entering Lake Pontchartrain. Seasonal emergence of insects inhabiting rivers would also affect the food supply. Stations grouped as "open-lake" areas were dominated by Bivalvia and Mysidacea. Chironomidae larvae also were important foods. Food availability in open lake habitat appeared more stable than that

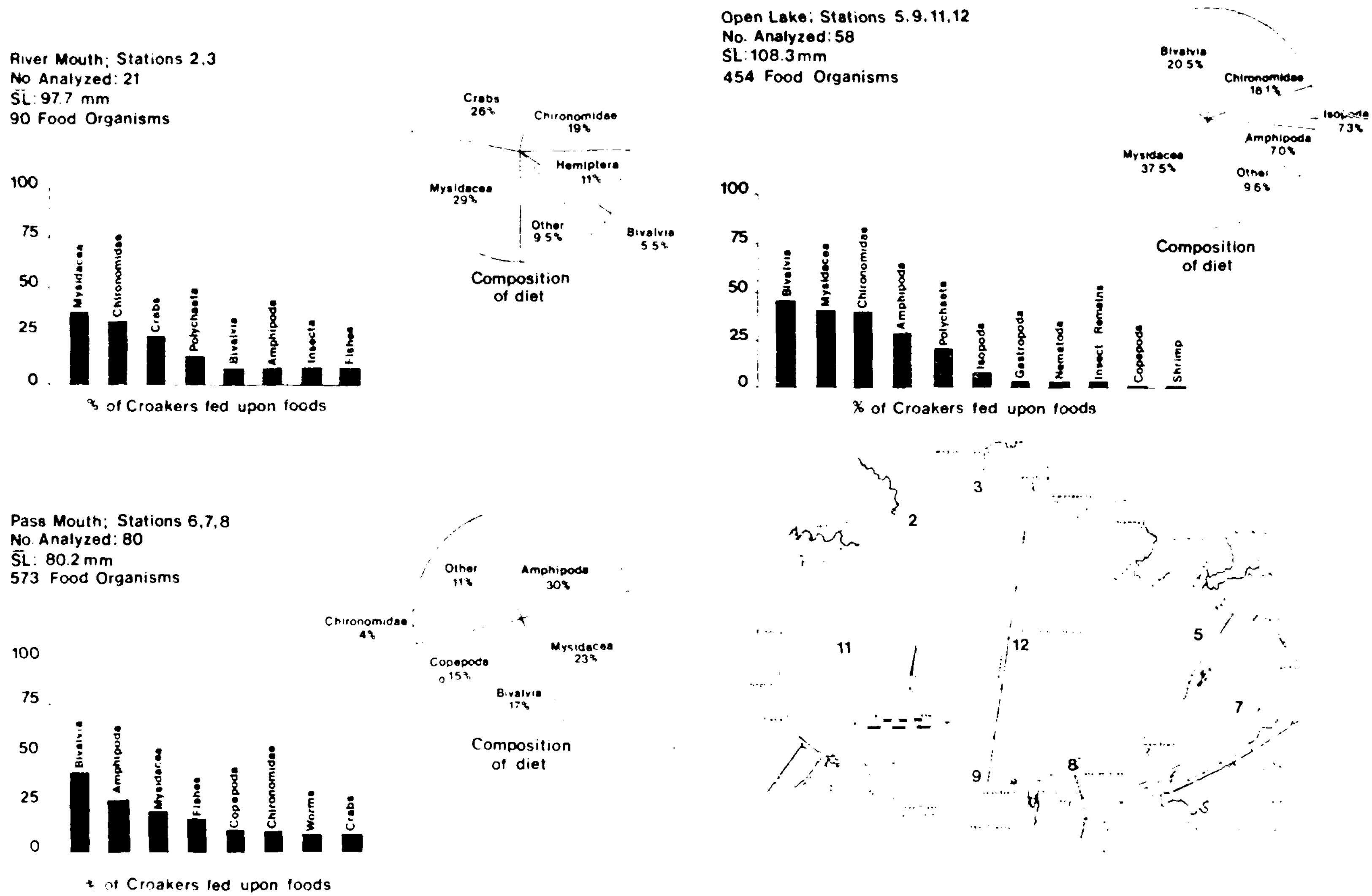

Figure 11. Geographic variation in feeding among Micropogonias undulatus from Lake Pontchartrain, LA, 1977-1978.

observed in river mouth areas. Heavy reliance upon bivalves and mysids was easily explained because they were not subject to extreme fluxes in abundance and were always plentiful during collection of croakers. "Pass mouth" stations differed greatly from other habitats: they were deeper, generally more saline, and were directly affected by tides. Transport of mysids and other potential foods through the passes was periodically heavy (Fannaly, Chapter 15). Slack tide lasting from half an hour to many hours slowed organism transport. Transport was frequently a one-way process for days at a time when heavy winds and rains forced continuous out- or in-tides. In a dynamic yet unstable, diverse habitat such as the mouth of a tidal pass, opportunism in feeding would be expected. Chironomidae larvae were less abundant and available in the greater depth and higher salinities of the pass mouths. As shown in Figure 11, chironomids were eaten by 11.3% of the fishes analyzed from pass mouths and were just 4% of the total diet by frequency. These numbers compare with respective counts of 33.3% and 19% from river mouths and 43.1% and 18.1% from open lake areas. The difference is not due to growth-related factors, since size classes from all three habitat types were strong consumers of chironomids when available (Fig. 10). In contrast to reduced availability of midge larvae, fishes, especially postlarval and juvenile fishes, were more abundant due to tidal transport through the passes (Fannaly, Chapter 15). Consumption of fishes was higher in pass mouths than in other habitat groups. Sixteen and three-tenths percent of the croakers from the pass mouths fed upon fishes, nearly twice the incidence observed in river mouths.

G. Leiostomus xanthurus Lacepede. Spot.

Food and feeding in L. xanthurus have been researched by Linton (1904), Smith (1907), Welsh and Breder (1923), Hildebrand and Schroeder (1928), Hildebrand and Cable (1930), Gunter (1945), Roelofs (1954), Reid (1954), Townshend (1956), Van Engel and Joseph (1968), Diener et al. (1974), Stickney et al. (1975), and Chao and Musick (1977). Darnell (1958) examined 56 spot (40-203 mm) from Lake Pontchartrain. He reported that young spot (≤ 99 mm) fed just above the bottom on microcrustaceans and small mollusks. With increasing size, feeding was directed progressively deeper into the bottom and burrowing forms increased in the food. A "wide variety" of foods was observed. Chao and Musick (op. cit.) reported similar feeding and food.

In the current study, 197 spot (12-252 mm) were analyzed, and as reported elsewhere in the literature, the food was diverse (refer to Fig. 12). Nearly 70% of the spot fed upon bivalves (Congeria leucophaeta, Ischadium recurvus, Macoma mitchilli, Rangia cuneata, and Mulinia pontchartrainensis). Bivalvia were over 27% of the total food. Copepoda (largely bottom-dwelling harpacticoids) occurred in over 50% of the stomachs and were over 57% of the total food. Chironomid larvae were eaten by nearly 50% of the spot. Midges comprised just 2.2% of the total food by frequency. Amphipoda (at least nine species, including Monoculodes, Corophium, Gammarus, Melita, and Grandidierella spp.) occurred in over 30% of the guts and were a small portion of the total food. Many other organisms entered the diet in small, varying amounts. Hydrobiid gastropods were slightly over 7% of the total ration and occurred in nearly 25% of the spot. Polychaeta, Cladocera, Ostracoda, Isopoda, Mysidacea, and Decapoda were consumed. Vegetable material,

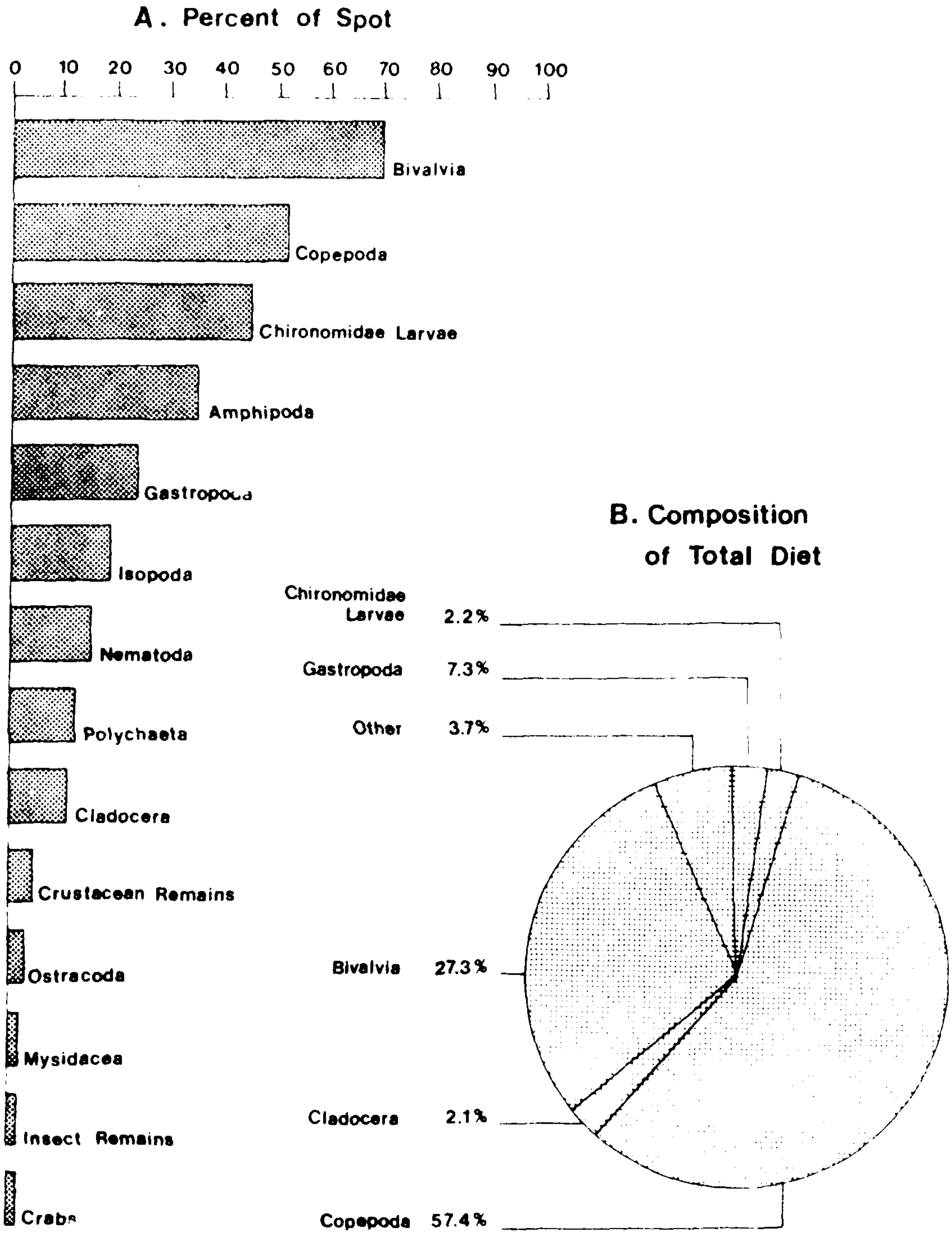

Figure 12. Percent of fish that consumed each food taxon (A) and percent frequency of the foods (B) among Leiostomus xanthurus from Lake Pontchartrain, LA, 1977-1978.

detrital and organic matter, fish eggs, and amphipod tubes regularly were observed in guts. Sand was in 31% f the tracts.

Most food organisms were benthic and/or infaunal forms. Food of spot contrasted greatly with that of croaker. L. xanthurus consumed many fewer mysids, tremendously more copepods and gastropods, and a broader variety of crustaceans than did M. undulatus. Croakers were heavier predators upon worms, decapods, chironomidae, and fishes than were L. xanthurus. Presence of sand and other miscellaneous material in spot tracts indicated considerable feeding "into" the substrate. Croakers appeared to feed "into" the bottom to some extent but fed more frequently on and near it.

Sheridan (1978, unpublished) reported no feeding progression with growth among spot from Appalachicola Bay. Darnell (1958) suggested that burrowing forms assumed more importance as spot grew. The present data showed definite changes in food with growth, but the pattern differed from those seen among other sciaenid fishes. Figure 13 traces growth-related feeding changes for several important food groups among L. xanthurus. With growth, other sciaenids, such as the croaker and seatrouts, fed increasingly upon more macromobile organisms. Foods also increased in size as selective predation replaced generalized foraging. This was not true among spot, and Darnell (op. cit.) was partially correct in his observation of increased infaunal feeding with growth. Po.ychaetes fluctuated but remained in the diet through all size classes except the second largest. Incidence of epibenthic hydrobiid gastropods increased rapidly with growth; no feeding upon them was seen until spot attained 51 mm. Bivalvia also rapidly became a dominant food. Copepoda (primarily

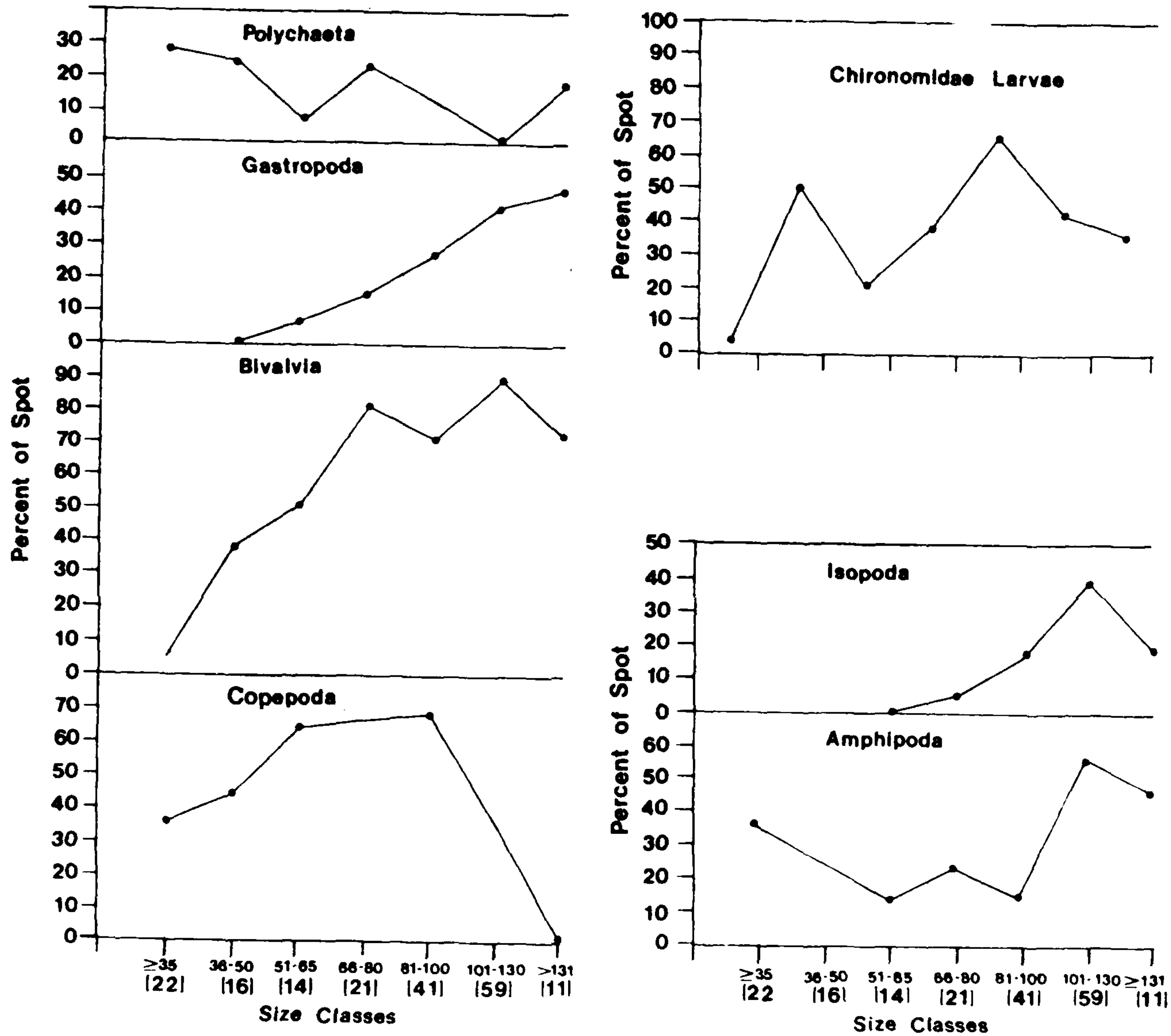

Figure 13. *Growth-related feeding changes among Leiostomus xanthurus from Lake Pontchartrain, LA, 1977-1978.*

benthic harpacticoids) were heavily preyed upon in the smaller size classes but ceased to be an important food item after spot reached 100 mm. Isopoda were consumed after 66 mm and increased strongly until 101-130 mm, when a sharp drop was observed. Amphipoda maintained a moderate, fluctuating occurrence in spot stomachs and appeared to increase among the largest size classes. Chironomidae larvae also were eaten irregularly but were heavily utilized among spot larger than 56 mm. Infaunal bivalves and epibenthic gastropods seemed major foods of more mature spot. Copepoda was the sole taxon to drop completely from the food with growth; other main groups listed remained substantial foods. L. xanthurus showed growth-related feeding changes but did not progress to more specific predation or to utilization of large organisms. Generalized feeding upon small organisms was characteristic of spot.

Station-by-station comparison among L. xanthurus was limited to stations fished by trawl only. Figure 14 shows total diet composition by frequency at each site. Gastropods were first or second in importance at all stations except number three. Bivalvia were of first or second importance at three of the six stations depicted. Station 12 (S12), located midway along the Pontchartrain Causeway, was notable because Bivalvia were just 4% of the total food. No other station yielded so few bivalves. The lake area surrounding most of the Causeway is heavily dredged for shell and scarcity of small bivalves may reflect this impact. Chironomidae larvae were present at half the stations in percentages ranging between 6% and 21% of the total food. Station 3, a river mouth area, provided no chironomids for L. xanthurus. Station 5, a generally more saline open-lake site, also yielded no midge larvae. Copepoda were counted from four of the six stations. Their numbers varied from 53% of

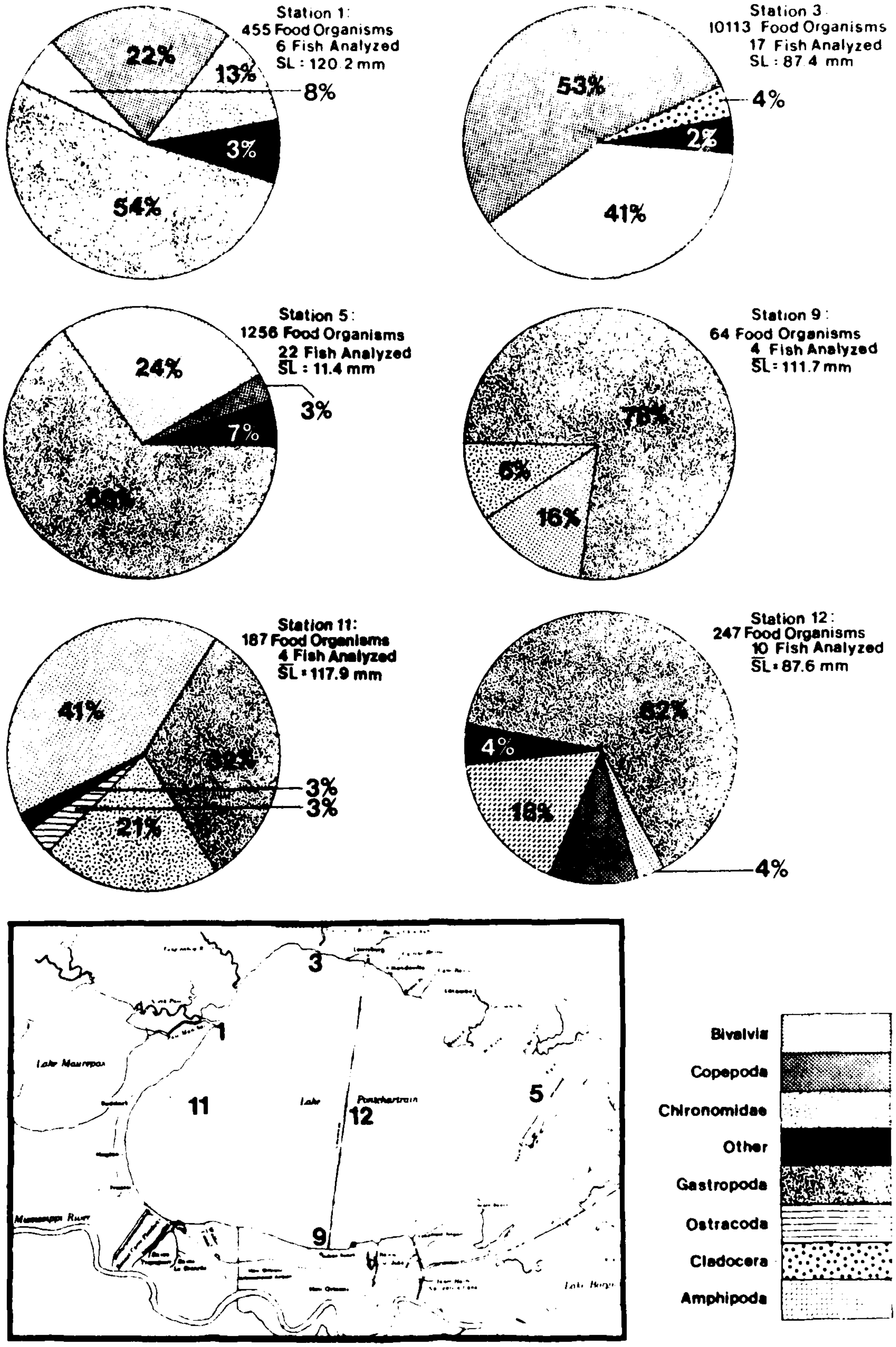

Figure 14. Geographic variation in feeding among Leiostomus xanthurus.

the total (S3) to three percent (S5). Since Copepoda were earlier shown to be a growth-variable food, their pattern of occurrence by station seemed more a consequence of the size of spot collected rather than habitat related. Amphipoda were 18% of total food at S12 and were absent or incidental elsewhere. Cladocera (S3) and Ostracoda (S11) occurred in small numbers at relatively less saline west-side stations.

H. Pogonias cromis (Linnaeus). Black Drum.

P. cromis is a semispecialized bottom feeder. Mollusks and crustaceans are most commonly eaten, although fishes also enter the diet (Smith 1907, Welsh and Breder 1923, Pearson 1929, Gunter 1945, Reid 1955, Van Engel and Joseph 1968, Fontenot and Rogillio 1970). Darnell (1958) examined 20 black drum (116-218 mm) with food from Lake Pontchartrain. Rangia cuneata and other mollusks were primary foods. Organic matter and the xanthid crab Rhithropanopeus harrisii also were fed upon.

In the present study, 11 P. cromis (54-620 mm) were studied. Two contained food. Remains of two unidentifiable fishes and small amounts of Rangia cuneata shells were in the guts.

VII. Sparidae

A. Archosargus probatocephalus (Walbaum). Sheepshead.

Darnell (1958) reviewed previous food studies of the sheepshead. A. probatocephalus forages in a picking, piecemeal fashion, employing well-developed incisors along hard surfaces, vegetated areas, and the bottom. Foods include crabs, barnacles, mollusks, and plant matter. Odum (1971) noted that in an Everglades estuary, very young sheepshead fed upon copepods, amphipods, chironomids, and small amounts of algae. At 35-40 mm, small mollusks entered the food and feeding over hard

substrates began. With further growth, generalized nibbling becomes the major feeding mode.

In the current study, six sheepshead (73-382 mm) were analyzed. Mollusca (Congeria leucophaeta and Rangia cuneata) were nearly 28% of the total food and occurred in one-half of the tracts examined. Crustacea (Gammarus tigrinus, Callinectes sapidus), were nearly 67% of the total food; 50% of the sheepshead consumed crustaceans. Insecta (Chironomidae larvae) and fish remains each were 3% of the total food and were eaten by 17% of the A. probatocephalus. Vegetable and other matter occurred in half the tracts. Frequently the digestive tract was packed with vegetation.

B. Lagodon rhomboides (Linnaeus). Pinfish.

Food and feeding among pinfish have been extensively studied on the Atlantic and Gulf Coasts. Feeding is marked by the same grazing, scraping, and picking as observed among sheepshead. Food selection has been described as generalized (Caldwell 1957) and specialized (Darnell 1958). Caldwell (1957) and Odum (1971) considered the pinfish a strictly diurnal feeder. Its foods included worms, crustaceans, mollusks, fishes, and vegetable matter (Goode 1884, Linton 1904, Smith 1907, Hildebrand and Schroeder 1928, Lamonte 1945, 1952, Gunter 1945, Gabrielson and Lamonte 1950, Reid 1954, Caldwell 1957, Springer and Woodburn 1960, Hansen 1969, Odum 1971, Carr and Adams 1973, Diener et al. 1974). Kjelson et al. (1975) and Kjelson and Johnson (1976) showed that feeding rates of postlarval pinfish decreased as current velocity increased and that prey size increased with growth of the pinfish. Feeding in L. rhomboides 16-20 mm centered around Copepoda.

Darnell (1958) examined 99 pinfish (40-150 mm) from Lake Pontchartrain. He reported that food progressed from microbenthos to filamentous algae, zooplankton, mobile macrocrustaceans, and fishes. Pinfish of all sizes consumed vegetation. In the current study, 14 L. rhomboides (56-124 mm) were examined. The amphipods Gammarus mucronatus, Gammarus macromucronatus, the crab Rhithropanopeus harrisii, and the mysid Mysidopsis almyra comprised the predominant crustacean portion of the diet. M. almyra was 75% of the total food and occurred in 36% of the guts. Crustacea were consumed by 93% of the pinfish and constituted over 95% of the total food. Nereid worms and dipteran insects accounted for the remainder. Vegetable and other matter occurred in 57% of the tracts.

VIII. Bothidae

A. Paralichthys lethostigma Jordan and Gilbert. Southern Flounder.

Previous research characterized the southern flounder as predaceous upon fishes, shrimps, crabs, and mollusks (Gunter 1945, McClane 1948, Knapp 1949, Reid 1955, Fox and White 1969, Diener et al. 1974). Darnell (1958) examined 14 flounders (113-380 mm) from Lake Pontchartrain. Most of the food consisted of fishes (Anchoa mitchilli, Micropogonias undulatus) and crabs. In the present study, four P. lethostigma (102-300 mm) were analyzed. Seventy-five percent of the flounders fed upon fishes (the same two species cited by Darnell). A single Gammarus spp. amphipod was the only other food encountered.

IX. Soleidae

A. Trinectes maculatus (Bloch and Schneider). Hogchoker.

Food habits of hogchokers have been researched by Hildebrand and Schroeder (1928), Reid (1954), Darnell (1958), Van Engel and Joseph (1968), Odum (1971), Carr and Adams (1973), and Diener et al. (1974). Hogchokers predominantly feed on benthic and infaunal invertebrates such as polychaetes, microcrustacea, and chironomidae larvae. Darnell (op. cit.) examined three hogchokers (61-74 mm) from Lake Pontchartrain. *Corophium* spp. amphipods occurred in all three stomachs. Undetermined organic matter, chironomid larvae, microcrustacea, and vegetable matter comprised the remainder.

My analysis of *T. maculatus* was hindered by a large number of empty stomachs (69 of 110 stomachs contained food). Hogchokers are particularly prone to regurgitation, and many specimens lost their food prior to analysis despite great care taken in handling. As shown in Figure 15, foods included a variety of bottom invertebrates but were dominated by Chironomidae larvae. These were 81.7% of the total food and were fed upon by nearly 60% of the hogchokers. No other food taxon was more than 7.8% of the total food or was consumed by more than 27% of the *T. maculatus*. Abundance of chironomids seemed the cause of specialization, because the presence of other more mobile forms in the food (crabs, mysids) suggests that hogchokers are capable of more diverse feeding than was observed.

X. Gobiidae

A. Gobiosoma bosci (Lacepede). Naked Goby.

Diener et al. (1974) analyzed the food of 20 *G. bosci* (12-40 mm) from Clear Lake, Texas. Polychaetes, microcrustaceans, gastropods,

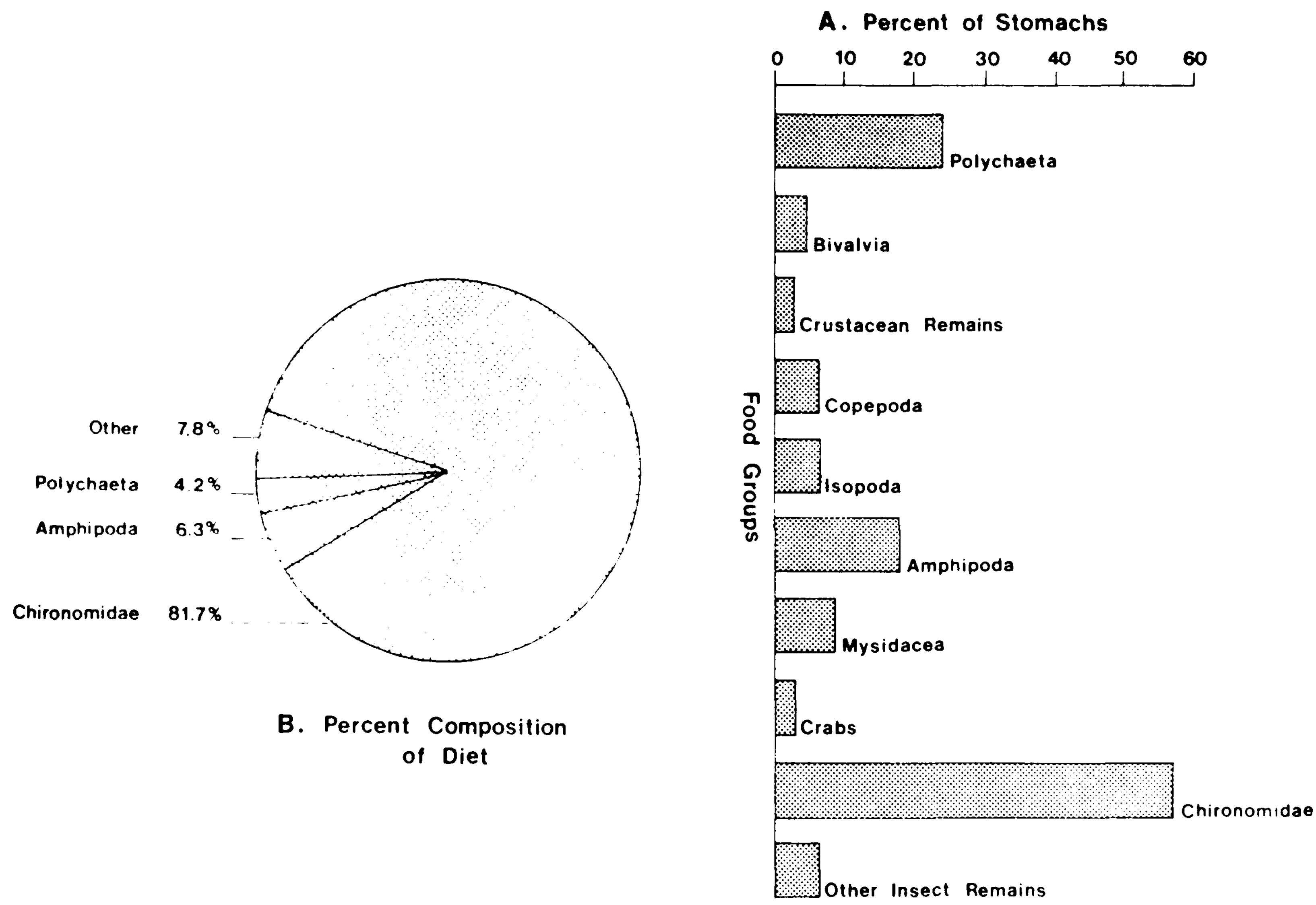

Figure 15. Percent frequency of the foods (A) and percent of fish that consumed each food taxon (B) among *Trinectes maculatus* from Lake Pontchartrain, LA, 1977-1978.

plant matter, and sand were reported as stomach contents. In the current study, 53 naked gobies with food were examined. These ranged in size from 35.2-48.4 mm. Eight species of Amphipoda dominated the food. Amphipods were 60% of the total diet and occurred in nearly 89% of the stomachs. Other foods in order of importance were midge larvae, polychaetes, *Hargaria rapax*, isopoda (*Cyathura polita*) fishes, and copepods (Fig. 16). Nearly one-third of the tracts contained sand and other material.

B. *Microgobius gulosus* (Girard). Clown Goby.

Springer and Woodburn (1960) and Odum (1971) reported that benthic invertebrates such as copepods, mysids, amphipods, polychaetes, chironomidae larvae, and mollusks comprised the bulk of the food of *M. gulosus*.

In the present study, four *M. gulosus* with food (35-48 mm) were examined. Chironomidae larvae were by far the primary food: 93.4% of the total organisms counted were chironomids, and three of the four clown gobies with food contained midge larvae. Other foods present in small quantity were polychaetes, *Corophium* spp. and *Gammarus* spp. amphipods, and crab remains. Sand and/or vegetable matter were present in the guts of half of the *M. gulosus* analyzed.

C. *Gobionellus shufeldti* (Jordan and Eigenmann). Freshwater Goby.

Diener et al. (1974) reported the food of nine freshwater gobies (23-51 mm) from Clear Lake, Texas. Oligochaetes, copepods, ostracods, and sand were the main foods. I examined six *G. shufeldti* (37.7-50.2 mm). Crustacea were 69% of the total food and were present in half of the tracts analyzed. Virtually all crustacea in the food were Copepoda, although Mysidacea, Amphipoda, and Decapoda were consumed. Chironomidae

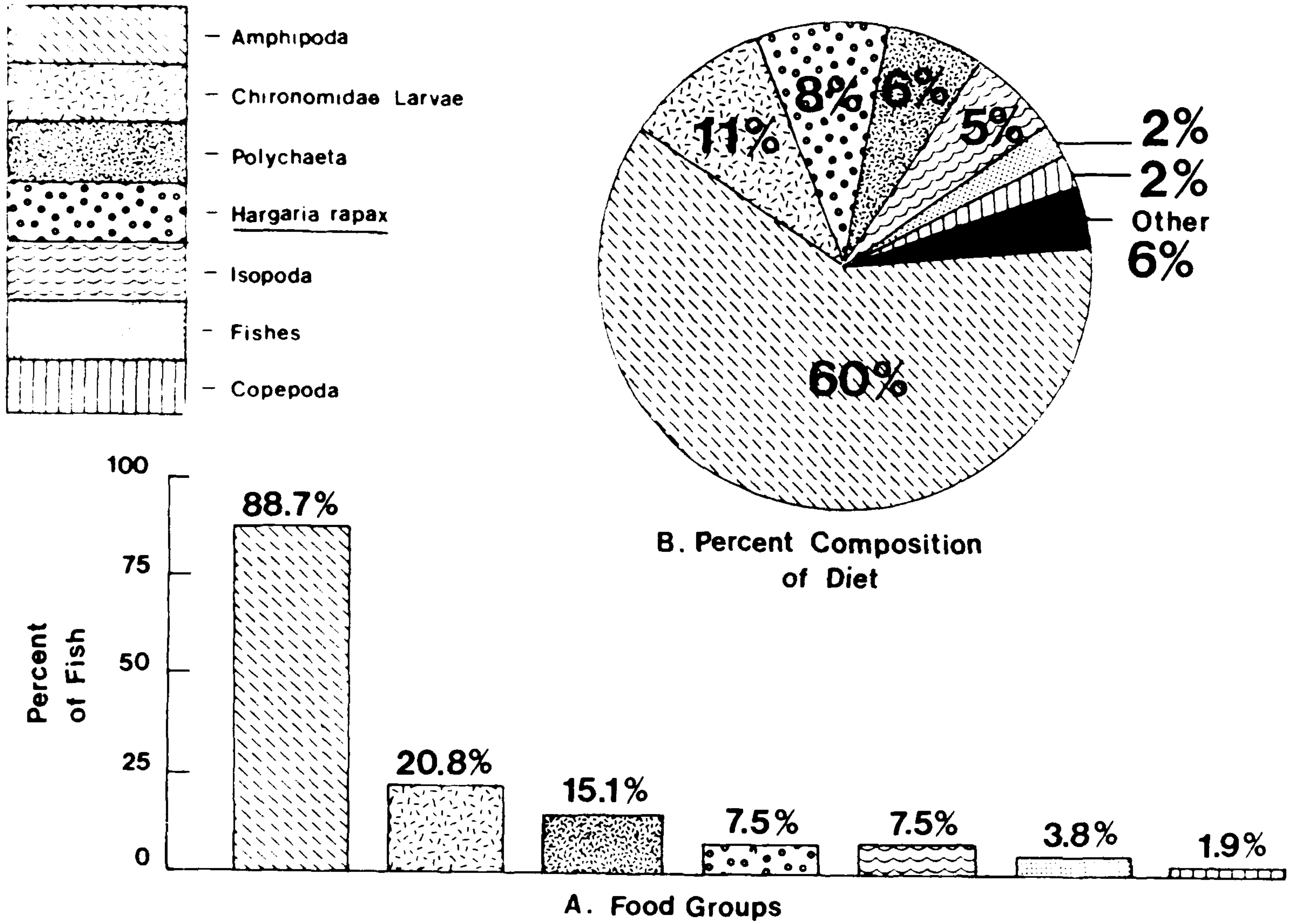

Figure 16. Percent of fish that consumed each food taxon (A) and percent frequency of the foods (B) among Gobiosoma bosci from Lake Pontchartrain, LA, 1977-1978.

larvae were 7% of the total food but were fed upon by 67% of the G. shufeldti. The mollusks Macoma mitchilli and Mulinia pontchartrainensis were 34.3% of the total food and were consumed by one-third of the G. shufeldti. One fish, Cyprinodon variegatus, entered the food.

XI. Gobiesocidae

A. Gobiesox strumosus Cope. Skilletfish, Clingfish.

Skilletfish feed largely upon benthic invertebrates but are known to prey upon nekton such as shrimp and fishes (Hildebrand and Schroeder 1928, Runyan 1961, Odum 1971, Diener et al. 1974). I analyzed 34 clingfish (23-27.5 mm) with food. The food was similar to that observed for Gobiosoma bosci with one important difference: both species fed largely upon benthic invertebrates such as amphipods (refer to Fig. 17 for diet of G. strumosus), but the clingfish fed more often upon mobile nektonic forms than did the naked goby. For example, Palaemonetes spp. shrimp were fed upon by the clingfish but not by naked gobies. G. bosci was preyed upon by G. strumosus in one instance. In the grassbeds where these fishes were syntopic, overall abundance with respect to foods and the above, slight difference in feeding would minimize competition. Since the species seem to rely so heavily upon amphipods, however, periodic drops in amphipod populations could lead to episodes of competition. Clingfish, which posses wider mouths relative to body size than do naked gobies, would be better adapted to an opportunistic diet (which would probably include G. bosci as prey).

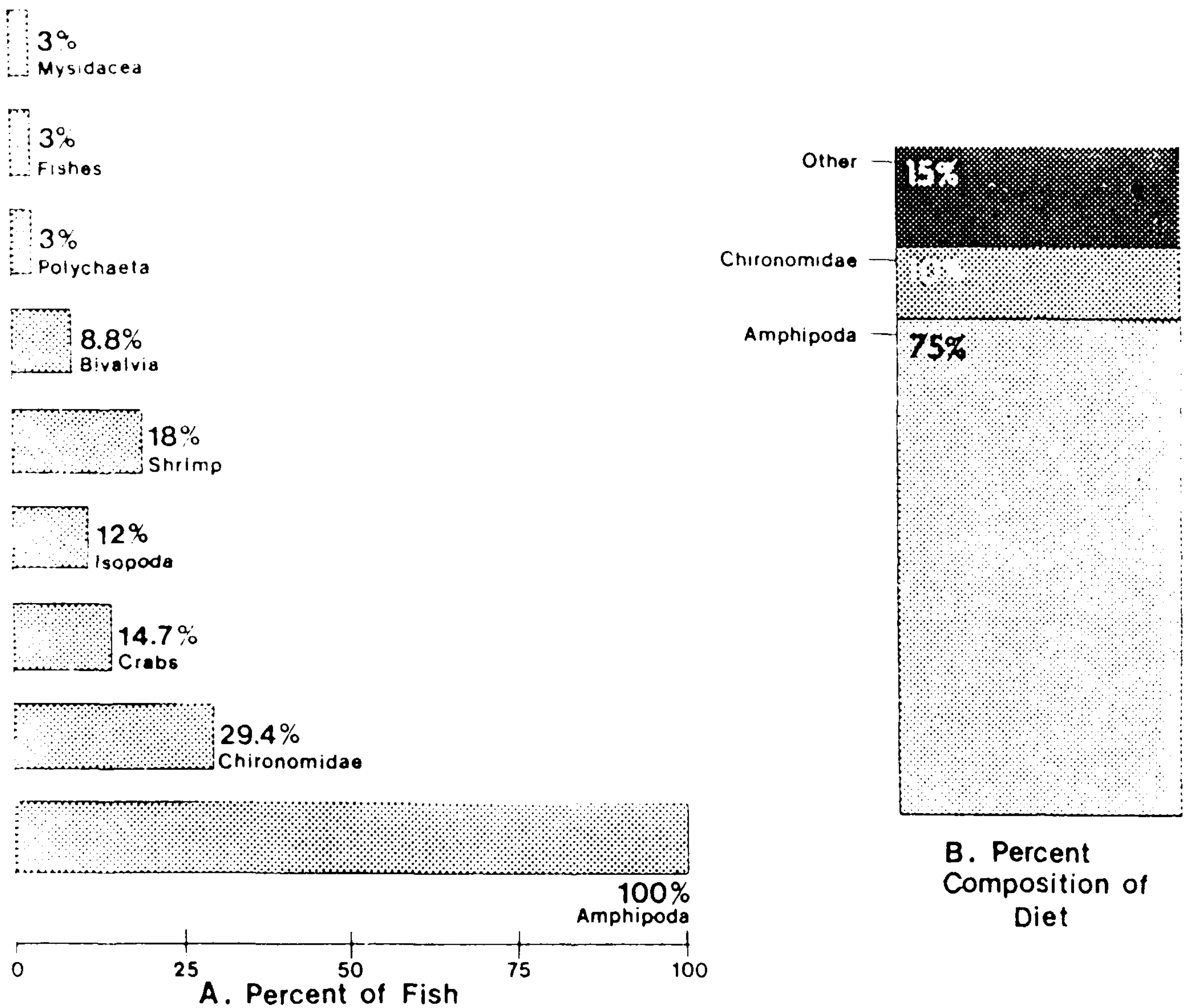

Figure 17. Percent of fish that consumed each food taxon (A) and percent frequency of the foods among Gobiesox strumosus from Lake Pontchartrain, LA, 1977-1978.

XII. Ariidae

A. Bagre marinus (Mitchill). Gafftopsail Catfish.

Food habits in B. marinus have been studied by Gudger (1916), Knapp (1949), Reid et al. (1956), Darnell (1958), and Diener et al. (1974). The species feeds primarily on Callinectes spp. crabs, penaeid shrimp, and fishes, although some utilization of small invertebrates occurs among the young.

Darnell (1958) examined one empty specimen from Lake Pontchartrain. In the current study, 10 B. marinus (78.9-457 mm) were analyzed. The specimens were taken from four-hour gill net sets and were unsuitable for food analysis because of advanced digestion. Thirteen food items were taken from the 10 catfish. Eight of these were fishes: Micropogonias undulatus and unidentifiables. Sixty percent of the catfish had fed upon fishes. Other foods were the decapods (Penaeus spp. and Callinectes sapidus, and the isopod Cyathura polita).

B. Arius felis (Linnaeus) Sea Catfish, Hardhead.

The sea catfish is a nonspecialized, bottom-oriented feeder that utilizes a wide variety of benthic and nektonic organisms. Carrion, organic matter, and detritus also are taken (Linton 1904, Smith 1907, Gunter 1945, Knapp 1949, Reid 1955, Ward 1957, Darnell 1958, Springer and Woodburn 1960, Hoese 1966, Diener et al. 1974, Hoese and Moore 1977).

Darnell (1958) analyzed 36 A. felis (90-269 mm) from Lake Pontchartrain. He recognized three feeding stages. Individuals smaller than 100 mm utilized zooplankton such as copepods. From 100 mm to roughly 200 mm, benthic microcrustacea and mollusks entered the diet. Above 200 mm, larger fishes and crabs gained importance. I examined 34 A. felis

(79-475 mm). A diverse assemblage of foods was observed, particularly with respect to the small number of catfish analyzed. As is typical for opportunistic, omnivorous fishes, feeding was not dominated by one or two food taxa. As shown in Figure 18, nine food groups occurred in 20% or more of the stomachs analyzed. Four groups were 10% or more of the total food, and none was greater than 23%. The xanthid crab Rhithropanopeus harrisii, an abundant benthic form, seemed selectively sought after, despite general omnivory. Crabs (R. harrisii and Callinectes sapidus) were most numerous in the stomachs and comprised most of the total food. Fishes (Brevoortia patronus, Dorosoma spp.. and unidentifiables) were second in overall importance. Chironomidae larvae were third in importance and were followed in decending order by Gastropoda, Insecta, Coleoptera, Amphipoda, Bivalvia, Mysidacea, Isopoda, Hymenoptera, Polychaeta, Cladocera, and Hemiptera. Insects in the food varied from ants to adult damselflies and included Belostoma (Hemiptera) spp., two families of Coleoptera, terrestrial Orthoptera, and four families of Diptera larvae. Vegetable and other material occurred in slightly over 25% of the tracts.

As mentioned above, feeding among hardheads is primarily bottom oriented. Mud crabs, amphipods, and chironomid larvae were most prevalent. Substantial predation throughout the water column (as shown by consumption of fishes and terrestrial insects) also occurred. Trophic ontogeny in my specimens was impossible to trace because 31 of the 34 specimens with food were of the same size class. Darnell (op. cit.) did not observe much feeding change with growth, but he did note that adult fish took larger foods and more crabs. He also reported an apparent increase in selectivity with growth.

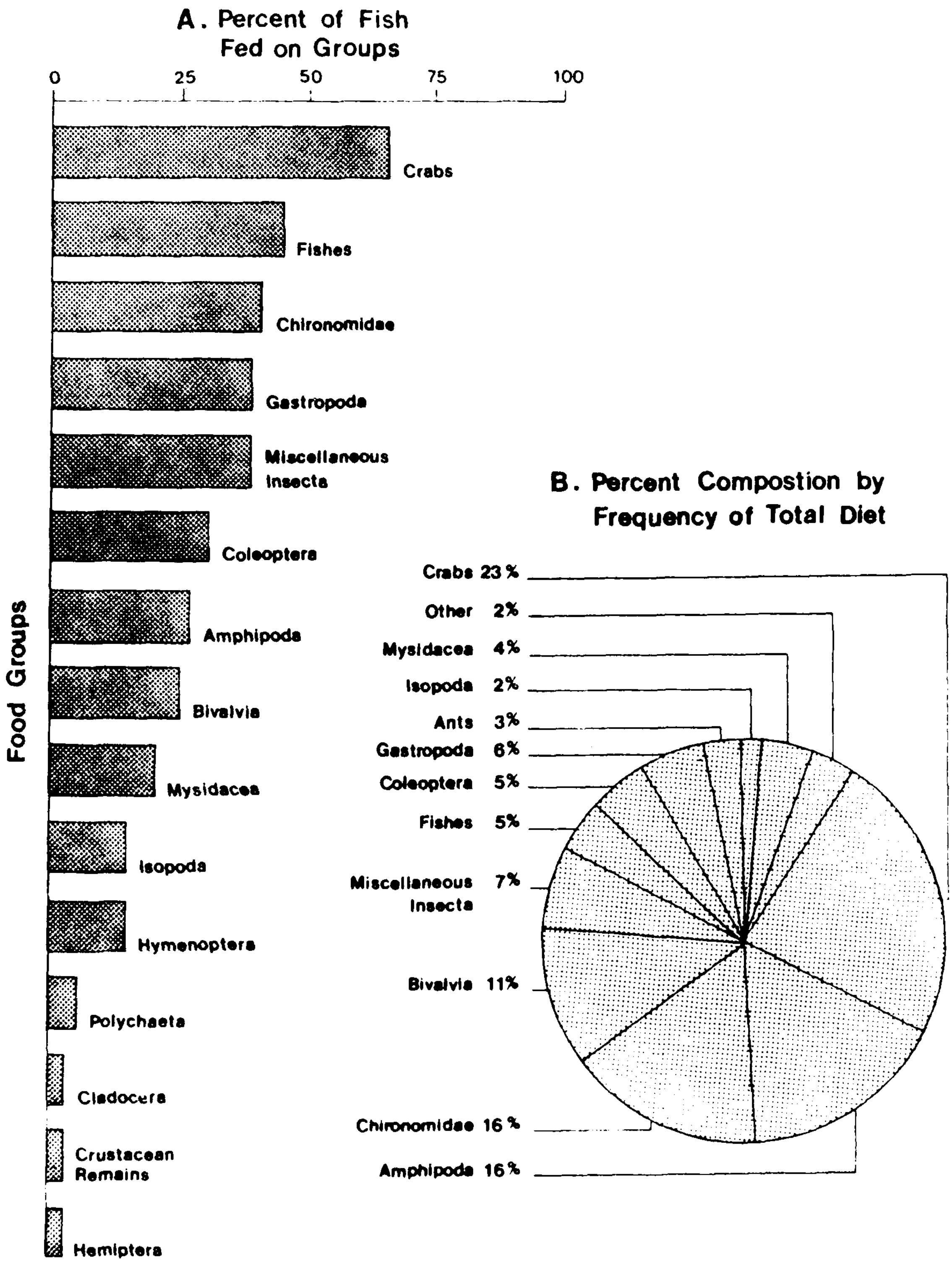

Figure 18. Percent of fish that consumed each food taxon (A) and percent frequency of the foods (B) among Arius felis from Lake Pontchartrain, LA, 1977-1978.

XIII. Ictaluridae

A. Ictalurus furcatus (Leseur). Blue Catfish.

The blue catfish has been described as a generalized feeder with complex food habits ranging from grazing and scavenging to piscivory. An extremely diverse list of invertebrate and vertebrate foods has accumulated (Forbes 1888, Forbes and Richardson 1920, Hildebrand and Towers 1927, Gunter 1945, Perry 1969). Research on food and feeding in estuarine I. furcatus is sparse, however.

Darnell (1958) examined 69 Blue Catfish (60-411 mm) from Lake Pontchartrain. In specimens smaller than 100 mm, zooplankton such as copepods were the main food. Small benthic organisms entered the diet after 100 mm, and catfish larger than 230 mm fed mainly upon "macro-mobile" animals.

In the present study, 112 I. furcatus (29.5-428 mm) were analyzed. Foods were numerically abundant and taxonomically diverse. Figure 19 summarizes my analyses. Bivalvia dominated the food. Congeria leucophaeta, Ischadium recurvus, Macoma mitchilli, Rangia cuneata, Mulinia pontchartrainensis, and unidentifiables were 76% of all food observed and occurred in over 80% of the tracts examined. Catfish often were packed with bivalves from esophagus to anus. Smaller bivalves less than one cm across the shell were usually eaten whole. Fragments of larger bivalves were observed also. Despite dominance of bivalves, other organisms were consumed. A typical sample of catfish stomach contents contained a diverse group of organisms. Polychaetes and other worms were a fraction of the total food and occurred in slightly over 10% of the stomachs. Gastropoda (small hydrobiids), Isopoda (Cyathura polita, Edotea montosa), Amphipoda (five species, three known genera, and

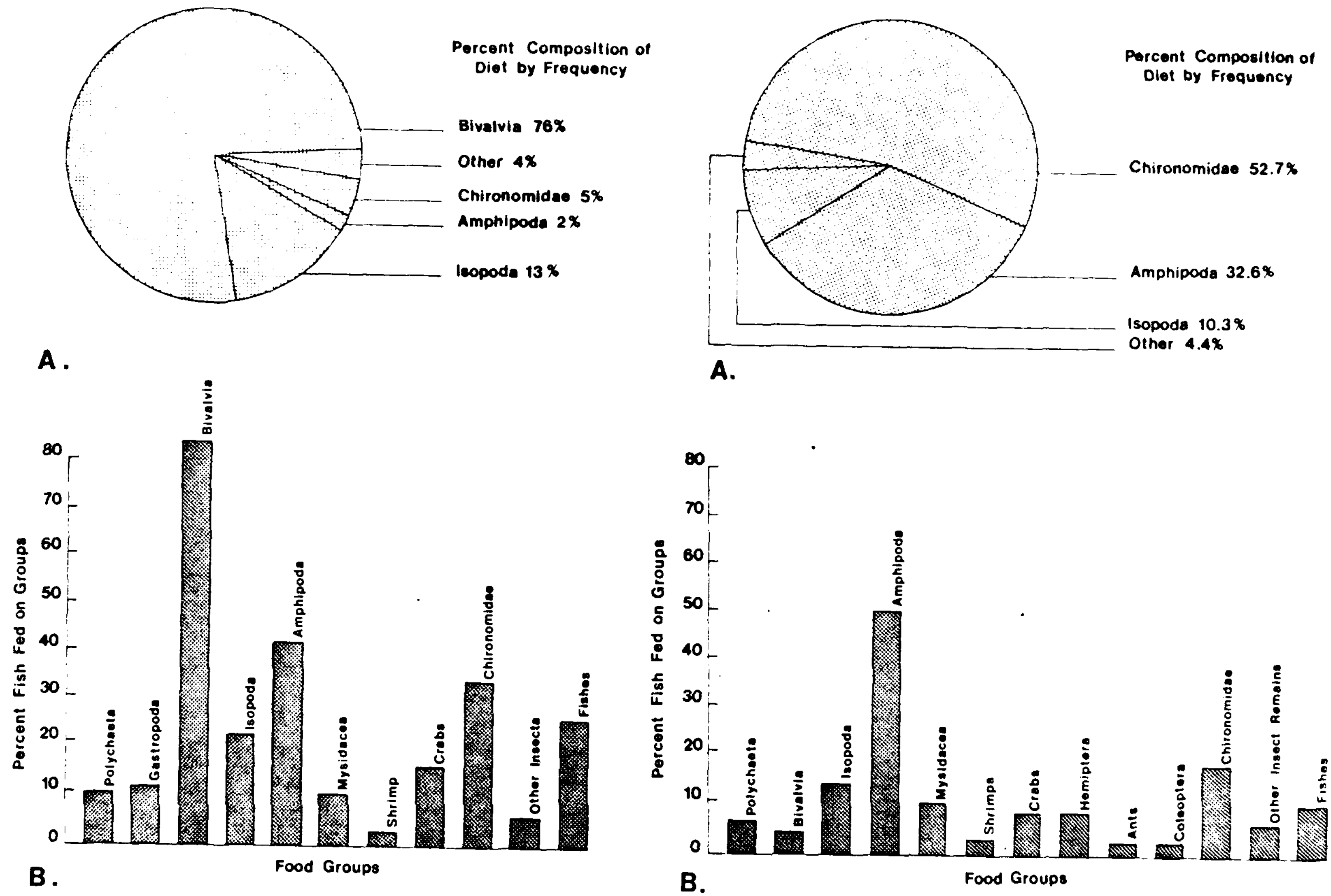

Figure 19. Percent frequency of the foods (A) and percent of the fish that consumed each food taken among Ictalurus furcatus and Ictalurus punctatus from Lake Pontchartrain, LA, 1977-1978.

unidentifiables occurred in over 40% of the tracts), crabs and shrimp (including the mud shrimp Callianassa jamaicense), Chironomidae larvae (occurred in over 30% of the tracts), and fishes all were important foods. Fishes were just 0.61% of the total food by number but occurred in over 30% of the tracts. Anchoa mitchilli, Brevoortia patronus, Micropogonias undulatus, Dorosoma spp., Arius felis, and numerous unidentifiables were consumed. Plant, bottom, and miscellaneous material were not common in the guts.

Foods of the blue catfish were similar to those of A. felis and indicated substantial insectivory. Partitioning in this case occurred as follows: sea catfish were most common in Lake Pontchartrain from May-October; blue catfish were most abundant December through May (Thompson and Verret, Chapter 12). The species were not totally mutually exclusive, but population overlap was minimal. Secondly, I. furcatus relied much more heavily upon bivalves than did A. felis; the latter seemed to selectively seek Rhithropanopeus harrisii. Trophic partitioning among I. furcatus and Ictalurus punctatus, the channel catfish, will be discussed in the following section.

Trophic ontogeny among blue catfish is traced in Figure 20. Although Darnell (1958) reported rapid decrease of feeding upon burrowing forms such as bivalves and primary predation upon "macro-mobile" organisms such as fishes and shrimp in adult I. furcatus, my data clearly showed bivalves as the major food across all size classes. Selective predation upon fishes and crabs also increased with growth of catfish. Smaller invertebrates such as amphipods and isopods decreased in the diet with catfish growth. The major isopod eaten was Edotea montosa, an abundant marsh and littoral species. Decreased predation upon E. montosa occurred

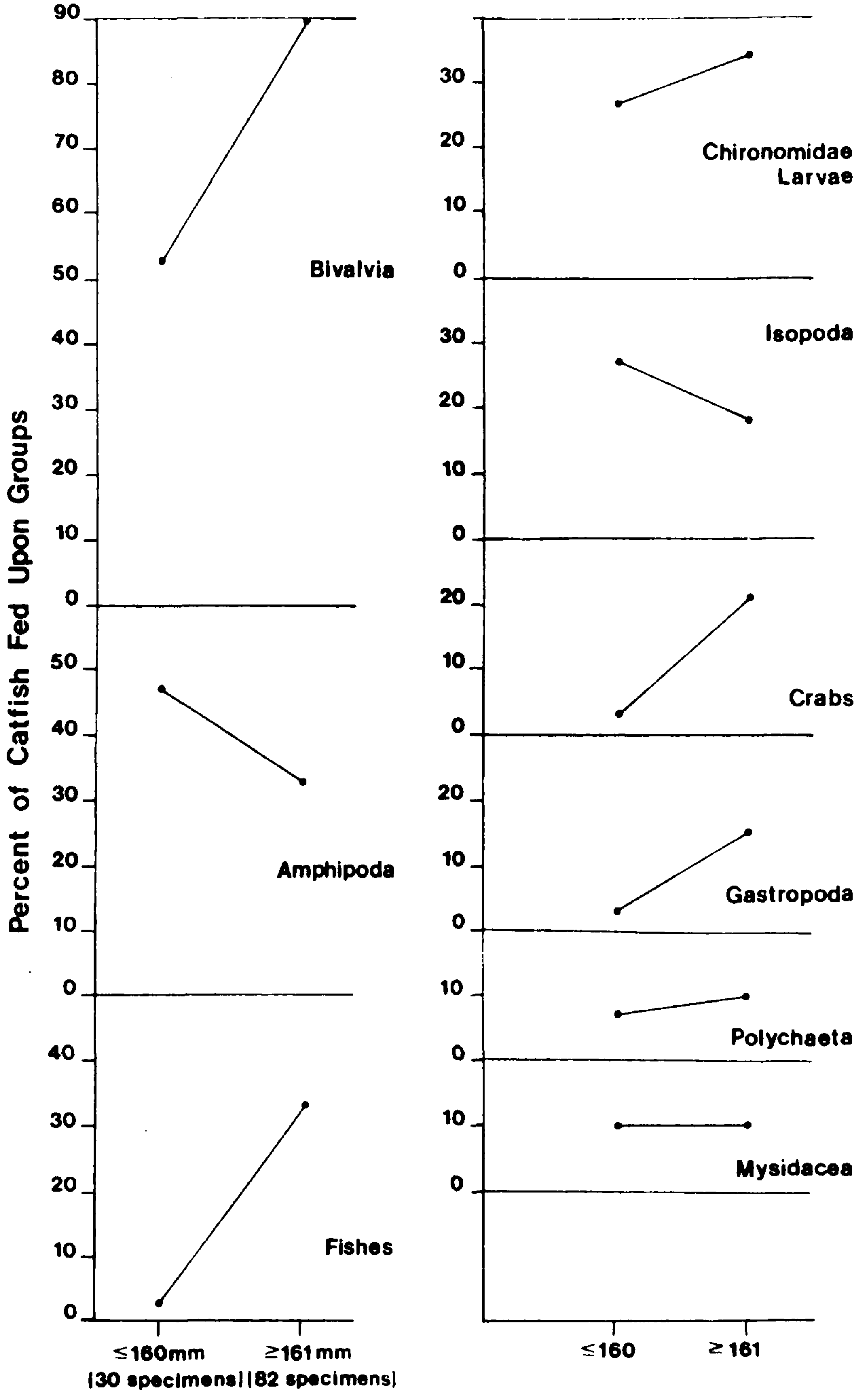

Figure 20. Growth-related feeding changes among Ictalurus furcatus from Lake Pontchartrain, LA, 1977-1978.

larvae and Amphipoda were the most important foods of channel catfish. At least nine species of amphipods entered the food, including *Corophium*, *Gammarus*, *Hyalella*, and *Grandidierella* spp. Other food taxa were isopods (primarily *Edotea montosa*), mysids (*Mysidopsis almyra* and *Taphromysis louisianea*), decapods (*Rhithropanopeus harrisii*, *Callinectes sapidus*, *Callianassa jamaicense*), insects (Hymenoptera, Coleoptera, Ephemeroptera, Hemiptera, Odonata, Diptera), fishes (*A. mitchilli*, *B. patronus*, *M. punctatus*, *Symphurus plagiusa*, *Heterandria formosa*, and unidentifiables). Vegetable and other matter occurred in approximately one-third of the tracts.

Blue and channel catfish are morphologically similar fishes. Each is a feeding generalist. Trophic partitioning in the heterogeneous Lake Pontchartrain system was straightforward. Figure 21 compares diets of these catfishes with respect to habitat. Two very different habitat-dependent situations emerged. In the marsh (S14), some dietary overlap occurred. Isopods were important foods among both catfishes: 28% of total food for *I. punctatus* and 75% for *I. furcatus*. Channel catfishes ate mainly amphipods (66% of total food), and after isopods and amphipods, other food taxa were of minor importance. Among blue catfish from this marsh site, Bivalvia at 10.6% were the second most common food (more than 30 times the incidence of Bivalvia than among channel catfish from the same site). Other foods were more diverse than for channel catfish but were not abundant in the stomachs. When foods from lake S10 and S11 were compared, trophic overlap was minimal. Primary food of channel catfish was Chironomidae larvae (74.4% of total), followed by Amphipoda at 9.3%, and nine other groups, none of which comprised over 4.1% of the total diet. Bivalves were absent. The overall diet was relatively high

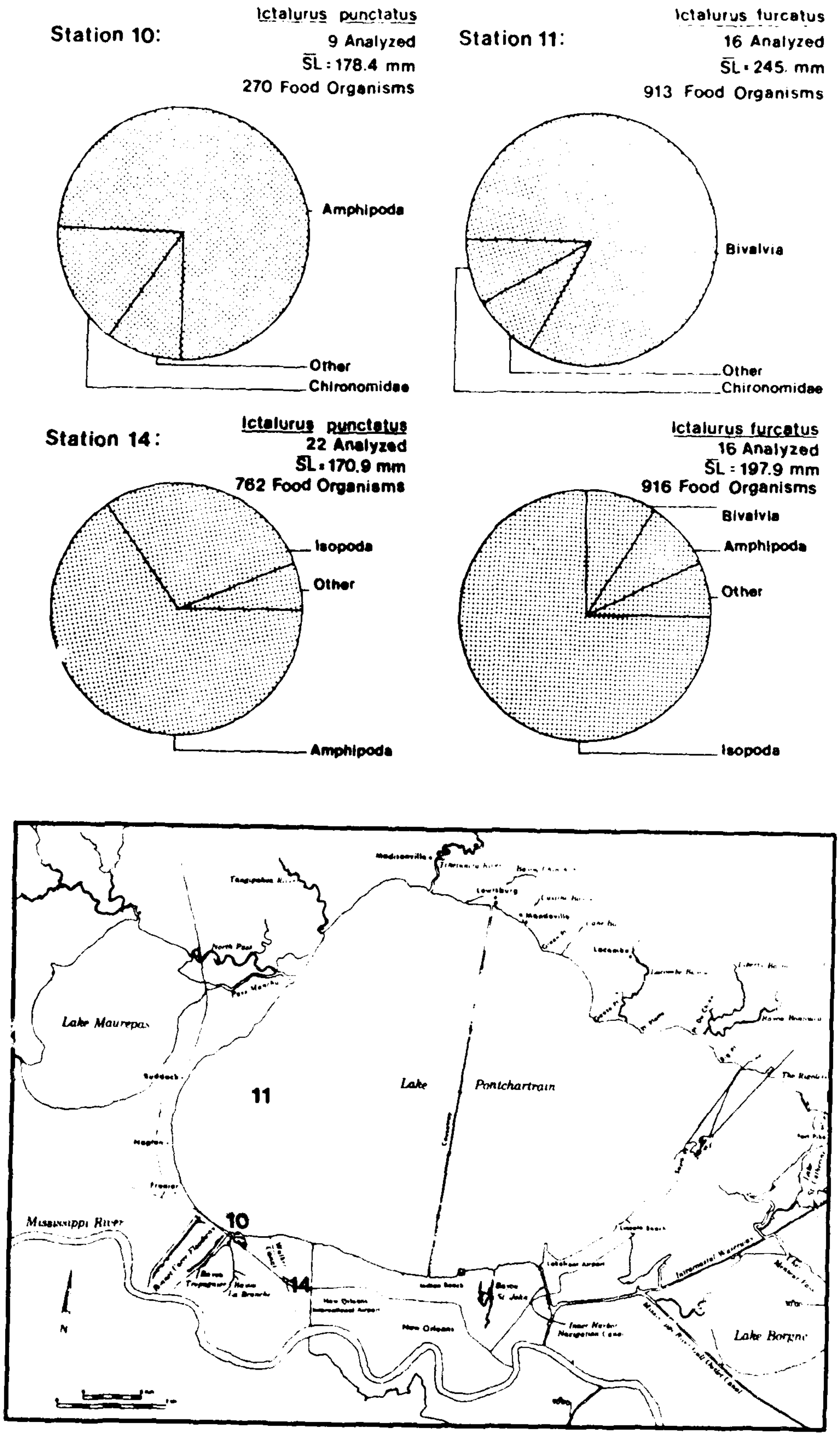

Figure 21. Comparison of geographic variation in feeding among Ictalurus punctatus and Ictalurus furcatus from Lake Pontchartrain, LA, 1977-1978.

with growth because larger blue catfish inhabited and fed in the open lake rather than marshes and near shore areas. Resource partitioning with the channel catfish, which was predominately a marsh fish (Thompson and Verret, Chapter 12), figured prominently here and will be discussed in the following section.

B. Ictalurus punctatus (Rafinesque). Channel Catfish.

Food and feeding in freshwater I. punctatus have been extensively studied (Forbes 1888, Smith 1907, McAtee and Weed 1915, Shira 1917, Mobley 1931, Ewers and Boesel 1936, Aitken 1936, Boesel 1938, McCormick 1940, Dill 1944, Menzel 1945, Dendy 1946, Bailey and Harrison 1948, Clemens 1954, Stevens 1959, Hoopes 1960, Russell 1965, Mathur 1966, Ware 1967, Perry 1969, Jearld 1970, Bonneau 1972, Levine 1977). The species is known as an opportunistic omnivore. Feeding progression occurs with growth, but generalized, complex feeding is a constant.

Darnell (1958) and Perry (1969) analyzed the brackish-water trophic relations of I. punctatus. Darnell (op. cit.) examined 13 specimens (76-119 mm) from Lake Pontchartrain. Small benthic invertebrates, insects, and bottom detritus were consumed. Darnell hypothesized that larger channel catfish continued to utilize the above foods and added fishes and larger crustaceans to the diet.

In the present study, 62 I. punctatus (25-443 mm) with food were analyzed. Foods were diverse and differed greatly from those observed from I. furcatus. Most evident was the lack of bivalve predation by channel catfish. Among blue catfish, five species of bivalves comprised over 75% of the total food and occurred in more than 80% of the stomachs. In channel catfish, bivalves were 0.24% of the total food and were in less than 20% of the stomachs analyzed. As shown in Figure 19, Chironomidae

in insects such as Hemiptera and ants. Blue catfish from S10 and S11 fed primarily upon bivalves, which comprised 85.3% of the total. Chironomidae were second at 10.1%, and seven other groups followed, none of which accounted for more than 1% of the total. Trophic separation was accomplished by nonoverlapping food preference and food availability with respect to habitat. Blue catfish were more likely to be abundant in the main lake (Thompson and Verret, Chapter 12) and to feed heavily upon abundant stocks of bivalves; channel catfish were more marsh/littoral oriented and fed heavily upon abundant midge larvae, amphipods, and isopods. In syntopic situations such as occurred at S14, food concentrations were large enough to allow feeding overlap.

XIV. Mugilidae

A. *Mugil cephalus* Linnaeus. Striped Mullet.

The striped mullet feeds primarily by selection of fine particles such as benthic diatoms, organic detritus, filamentous algae, and sediment particles. Bottom-oriented feeding occurs most frequently although occasional surface feeding has been observed (Linton 1904, Smith 1907, Jacot 1920, Hildebrand and Schroeder 1928, Ghazzawi 1933, Suyehiro 1942, Hiatt 1947, Reid 1955, Odum 1971, Moore 1974, Masson and Marais 1975). Bishop and Miglarese (1978) reported nektonic predation by adult mullet on *Nereis* spp. polychaetes. The authors cited other instances of selective, predatory feeding and concurred with Odum's (1970) statement that mullet will select food of higher caloric value when opportunity arises. Proteolytic enzymes occur in the digestive tracts of mullet (Ishida 1935), which indicates its possible ability to assimilate polychaetes and other protein-rich foods.

Darnell (1958) analyzed 54 M. cephalus (97-327 mm) from Lake Pontchartrain. His results agreed with general trends mentioned above. In the current study, nine mullet (89-232 mm) were examined. All contained varying amounts of detritus, plant matter, and sediment.

XV. Atherinidae

A. Menidia beryllina (Cope). Tidewater Silverside.

Tidewater silversides are aggressive predators of small arthropods and fishes. Opportunistic feeding upon insects that fall into the water also occurs (Hildebrand and Schroeder 1928, Reid 1954, McClane 1955, Harrington and Harrington 1961, Odum 1971). Darnell (1958) analyzed 60 silversides from Lake Pontchartrain. Isopods, amphipods, detritus, and zooplankton were consumed.

In the present study, 325 M. beryllina (21-84.5 mm) with food were analyzed. As shown in Figure 22, the diet was diverse and included organisms from throughout the water column. At 55.3%, calanoid copepods were the majority of the total food by frequency. Copepods are, however, limited in their importance in the overall ration to silversides. A large, diverse group of amphipods were clearly the major food: Amphipoda comprised 22.5% of the total food by frequency and occurred in over 80% of 325 stomachs that contained food. More than 12 species of amphipods entered the food. Identifiable were Monoculodes edwardsi, Corophium lacustre, Corophium louisianum, Orchestia spp., Gammarus macromucronatus, Gammarus mucronatus, Lepidactylus spp., Gammarus tigrinus, Grandidierella bonneroides, Melita nitida, and Cerapus spp. Chironomidae larvae were third in overall importance and made up 9.1% of the total diet. Nearly 30% of the stomachs contained midge larvae. Four species of fishes (Anchoa mitchilli, Menidia beryllina, Brevoortia patronus, Syngnathus

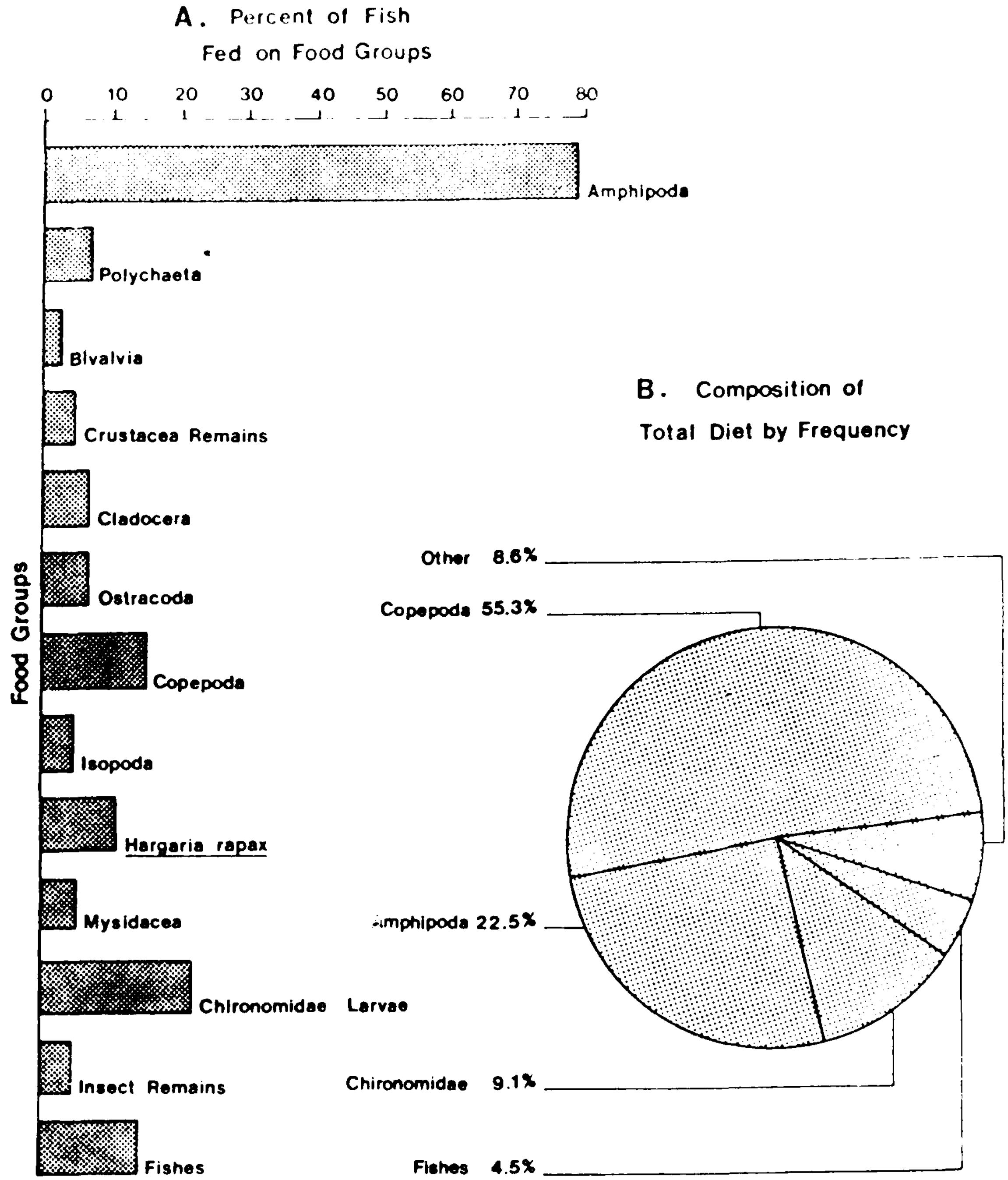

Figure 22. Percent of fish that consumed each food taxon (A) and percent frequency of foods (B) among *Menidia beryllina* from Lake Pontchartrain, LA, 1977-1978.

scovelli) and numerous unidentifiables were 4.5% of the total and occurred in approximately 16% of the stomachs. Silversides consumed more of the benthic tanaidacean Hargaria rapax than did any other fish analyzed: slightly more than 9% of the stomachs contained H. rapax. Foods of small numerical importance were polychaetes, bivalves, cladocerans, ostracods, isopods (primarily Cyathura polita), and mysids. Decapoda (mostly Callinectes sapidus) were another incidental food.

Darnell (1958) depicted trophic ontogeny among M. beryllina. He indicated that individuals smaller than 40 mm passed through a zooplankton-feeding stage and that larger fishes fed progressively with growth upon more mobile and large organisms. The present data showed no such clear progressive trends, however. As shown in Figure 23, Copepoda did appear to leave the diet with growth of silversides. Other foods fluctuated, although respective levels of frequency tended to hold through most size classes. Amphipoda, for example, were always most frequently present. Hemiptera (mobile insects) were not fed upon until the second largest size class. Ants that were present in the water were fed upon by fishes foraging opportunistically at the surface, but they occurred with low frequency after the 51 mm size class. Chironomidae larvae and fishes both fluctuated greatly.

Inconsistency in feeding among size classes indicated that silversides in Pontchartrain frequently switched food sources. The shallow littoral zone inhabited by M. beryllina (grassbeds present and absent) is co-inhabited by Fundulus grandis, Gobiesox strumosus, Microgobius gulosus, Syngnathus spp., Lepomis spp., Gobiosoma bosci and other fishes, all of which utilize in varying amounts the same organisms fed upon by silversides: amphipods, copepods, chironomidae larvae, crabs, and fishes. M. beryllina

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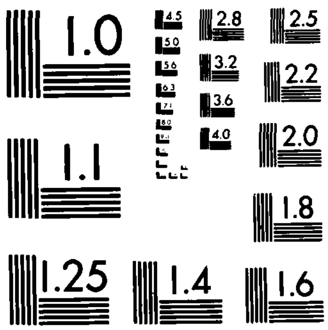

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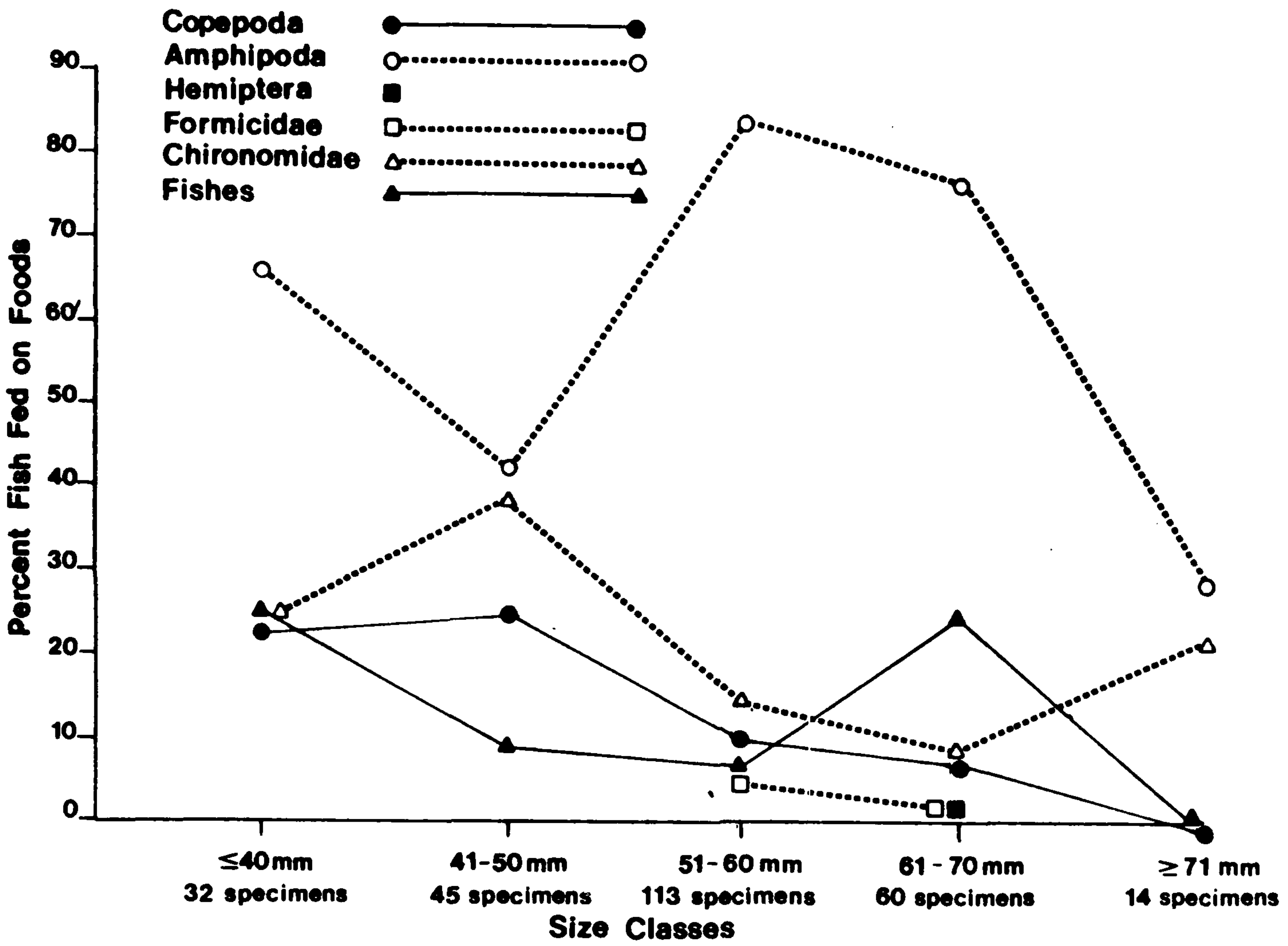


Figure 23. Growth-related food changes among _Menidia beryllina_ from Lake Pontchartrain, LA, 1977-1978.

adapted to competitive pressure by fully utilizing its ability to feed throughout the water column. Burrowing forms such as Hargaria rapax were eaten routinely by silversides but rarely by other fishes analyzed. Ostracoda and Cladocera also were more often preyed upon by M. beryllina than by other fishes. Cannibalism, rarely seen in other Lake Pontchartrain fishes, occurred to a substantial degree among M. beryllina. According to Murdoch et al. (1975), true switch-feeding fishes show relatively weak preference for alternative prey and readily take more abundant or otherwise more available prey. Mechanisms involved in switching (avoiding previous prey, selecting new prey) should result in specialization by individually predaceous Menidia beryllina. Love and Ebeling (1978) stated that if a large proportion of the analyzed stomachs contained one and not a combination of prey types, then switch-feeding was indicated. This seemed the case among silversides analyzed herein.

Fishes generally switch from decreasing or less accessible preys as a matter of course, since changes in prey abundance are normal consequences of seasonality and related physicochemical changes (Love and Ebeling 1978). M. beryllina in Lake Pontchartrain are not wide-ranging migratory fishes (Thompson and Verret, Chapter 12) and are limited to food sources within their immediate environment. Therefore, variation in prey availability from station to station should have been shown by feeding differences in M. beryllina collected at different stations. These are depicted in Figure 24. Unfortunately, the data in the figure do not take seasonal factors into account; discussion must therefore be limited to stable physical traits of the stations compared.

Stations 4 and 6 are both sandy-bottomed sites that support dense aquatic vegetation most of the year. Station 4, however, lacks the

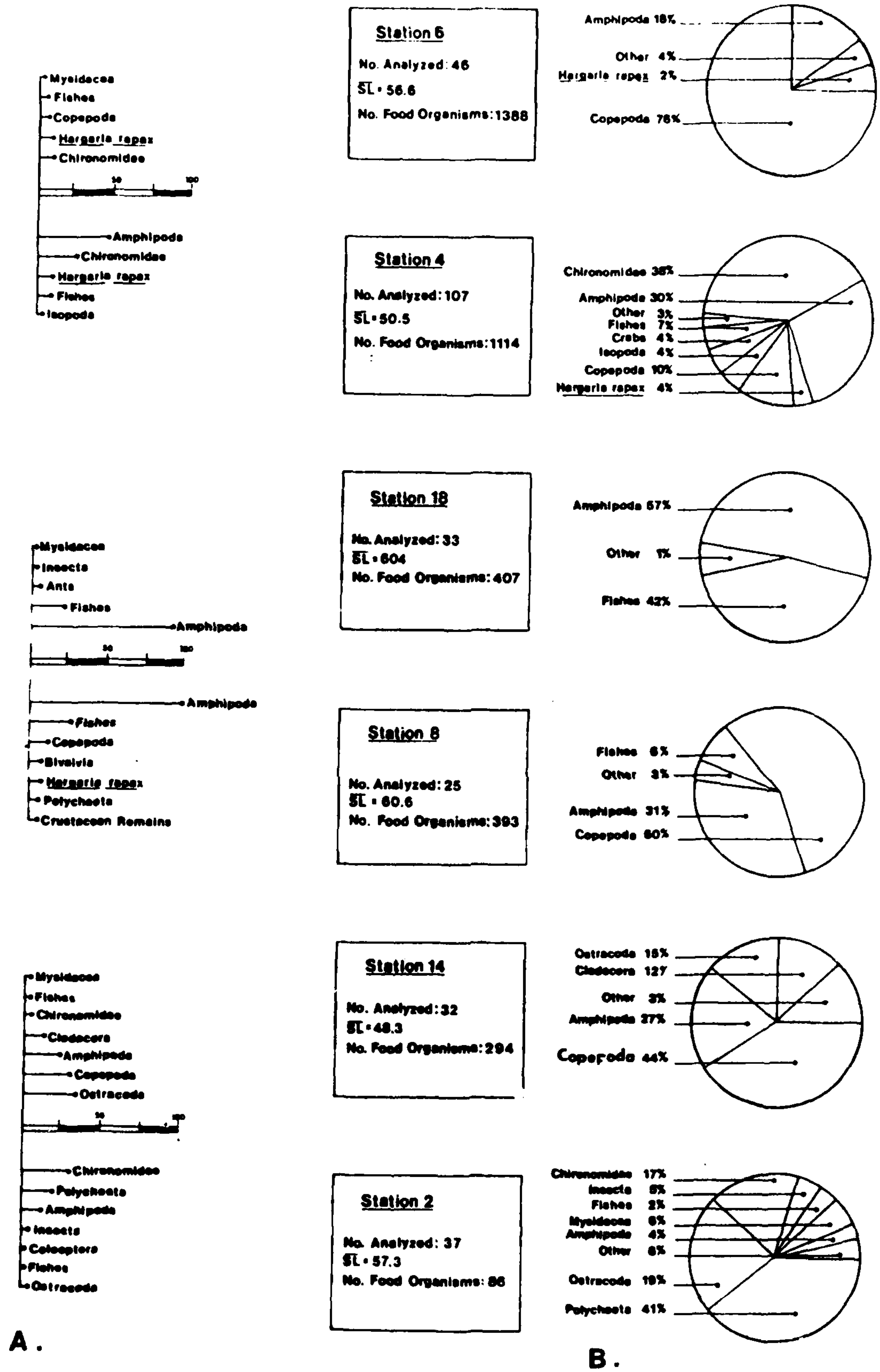


Figure 24. Geographic variation in feeding among *Menidia beryllina* from Lake Pontchartrain, LA, 1977-1978.

dynamic tidal input available to S6, since the latter is located just at the mouth of The Rigolets. Station 6 was more variable with respect to salinity than S4 was; the highest recorded salinity of our study (8.4) occurred at S6 during November 1978. Turbidity also varied more greatly at S6: east winds, for example, forced turbid Pearl River water through The Rigolets, and the collection site water levels were also subject to frequent change. Relative unstability of conditions at S6 was reflected when foods were compared with those from S4 silversides. Diet from the latter station was much more diverse; chironomidae larvae and amphipoda were most important. Station 6 silversides utilized copepods and amphipods most often; amphipods occurred in 97.8% of the stomachs from this station. Great abundance of one or two food taxa is indicative of instability among invertebrates available for food. As mentioned above with reference to switch-feeding, M. beryllina fed mainly upon those foods most easily available. Food resources at S4 seemed more stable.

The second geographic comparison involves S8 and S18. Station 8 was a hard sand and riprap-bottomed manmade area off the mouth of the Inner Harbor Navigation Canal (IHNC). Rooted aquatic vegetation was absent, but algae grew abundantly on riprap and concrete breakwaters. Breakwaters sheltered the site from wave action, and turbidity was variable. Station 18 was a north shore site similar to S4 but without grassbeds. Proximity of a tidal pass did not seem related to a less diverse diet among Menidia spp. at S8. Amphipoda and Copepoda were most important, and bottom-oriented foods were lower frequency foods. The hard sand bottom at S8 seems to be relatively depauperate of benthic organisms; several researchers have noted the unsuitability of such substrates as feeding niches for benthic fishes (Beck 1977, Levine 1977).

Amphipoda occurred in 100% of the stomachs analyzed from S8. Feeding at S18 was predominately upon fishes and amphipods, and the food was less diverse than at S8. Lack of aquatic vegetation limited diversity among invertebrates at this site. Amphipoda occurred in 90.9% of the stomachs. In this comparison, the sheltered nature of S8 apparently fostered higher stability than would be expected at a site so near to a tidal pass. Lack of true benthic fauna was counterbalanced by plentiful zooplankton and amphipoda, the latter inhabiting man-made hard substrates overgrown with algae and large aggregates of organic detritus. Station 18 offered a limited food complex, a result of near-absence of aquatic vegetation.

The third habitat comparison involves S2 and S14. Station 2 was located at the mouth of the Tangipahoa River on a shell, mud, and sand island. Collections were made on the lakefront side of the island (site devoid of vegetation) and in a backwater pool on the river side, which possessed a soft mud bottom overgrown with algae. The backwater pool was less than 15 cm deep and was subject to very wide temperature variations. In summer the pool commonly was measured at 30° C. Riverine habitats are characterized by changes in water levels and temperatures according to river discharge. Terrestrial insects and those inhabiting rivers as larvae (Ephemeroptera, Diptera) would also be available as food. Foods from silversides from S2 were indicative of a primarily freshwater habitat (salinities here were lowest of all nekton stations [Thompson and Verret, Chapter 12]). Ostracoda were important in the diet, as were beetles and other insects. Chironomidae larvae were consumed by more silversides (27%) than other foods, but no one food dominated the diet, which indicates the stability and diversity of food sources. Polychaetes

comprised 11% of the food by frequency. Feeding at S2 was accomplished throughout the water column. Station 14 was a small marsh stream feeding the Walker Canal in St. Charles marsh. Turbidity characteristically was high, and water levels varied greatly. Rooted aquatic vegetation and algae were plentiful, and substrates were strictly soft marsh mud. Diet of silversides from this habitat was diverse but lacked the insects notable at S2. Ostracoda were important foods here, as were Cladocera. In this respect S14 was similar to S2: the above two crustacean taxa were of minor or no food importance elsewhere. Mean salinities (1977-1978) for S2 and S14 were 0.6 and 1.7°/₀₀, respectively (Thompson and Verret, Chapter 12). Hargaria rapax, the burrowing tanaidacean actively selected for by silversides from more saline stations such as S8 and S6, was absent from the food at S2 and S14.

B. Membras martinica (Valenciennes). Rough Silverside.

Food habits of Membras martinica seem largely unstudied. I analyzed 67 rough silversides (32-102.6 mm) with food. Four specimens were part of regular daytime sampling. Copepoda were 90.9% of the total food. Hymenopteran insects, chiromomidae larvae, and organic material comprised the remainder.

Sixty-three rough silversides were dipnetted from The Rigolets and the IHNC at several time intervals during June, July, and August 1978 plankton 24-hour studies. More than 41% of the silversides fed upon insects. All consumed insects were of terrestrial origin. Twenty percent of the M. martinica fed upon Mysidacea, Amphipoda, and Polychaeta. July and August collections showed strong feeding peaks at 2200 hrs at both passes. Feeding was slight but regular between midnight and dawn. As was reported in the case of Strongylura marina, feeding behavior

clearly revolved around plentiful supplies of allochthonous organisms such as terrestrial insects.

XVI. Polynemidae

A. Polydactylus octonemus (Girard). Atlantic Threadfin.

Gunter (1945) reported that threadfins utilize enlarged pectoral fins as a "scoop-net" during feeding. Diener et al. (1974) examined one specimen that had fed upon a single Brevoortia patronus. I examined three specimens (107-119 mm). All fed upon Mysidopsis almyra. In view of Mysidopsis' importance as food to Cynoscion spp. and several other Lake Pontchartrain fishes, more examination of feeding in seasonally occurring threadfins is warranted.

XVII. Carangidae

A. Oligoplites saurus (Bloch and Schneider). Leatherjacket.

Feeding habits in O. saurus have been studied by Beebe and Tee-Van (1928), Springer and Woodburn (1960), Tabb and Manning (1961), Randall (1967), Odum (1971), Carr and Adams (1973), and Diener et al. (1974). Fishes and shrimp were reported as major foods. Carr and Adams (1973) recognized three major feeding stages among juveniles. Specimens 21-25 mm were planktivorous, specimens 26-40 mm fed largely by cleaning other fishes; and individuals 61-101 mm preyed upon small crustaceans. Planktivory persisted into the largest size class.

I examined one 55 mm leatherjacket. Four mysids were the only gut contents. Oligoplites saurus could be another seasonal member of the Pontchartrain fish community that heavily utilizes mysids.

XVIII. Poecilidae

A. Gambusia affinis (Baird and Girard). Mosquitofish.

Trophic characteristics of the mosquitofish have been widely studied (Barney and Anson 1920, Hildebrand and Schroeder 1928, Ward 1931, Hiatt 1947, Hunt 1953, Simpson and Gunter 1956, Harrington and Harrington 1961, Odum 1971). The species is a surface feeder upon insects and crustaceans and switches readily to an herbivorous diet.

I analyzed 14 mosquitofish from Lake Pontchartrain (17.8-38.8 mm). Cladocera (Daphnia spp.), Ostracoda, Copepoda, and Amphipoda were 85% of the total food. Insects (Hemiptera) were 15% of the total diet. Vegetable and miscellaneous matter occurred in only one tract.

XIX. Cyprinodontidae

A. Lucania parva (Baird). Rainwater Killifish.

Feeding ecology in L. parva has been studied by Hildebrand and Schroeder (1928), Simpson and Gunter (1956), Harrington and Harrington (1969), and Odum (1971). Small individuals consume planktonic copepods, and with growth, chironomids, amphipods, ostracods, mysids, and mosquito larvae enter the food.

In the current study, 37 L. parva (13-31 mm) were analyzed. Feeding was highly substrate oriented. Primary foods were bivalve remains (22% of total, consumed by 22% of fish), Amphipoda (five species, primarily Corophium lacustre and Grandidierella bonneroides); amphipods were 27% of the total and were fed upon by nearly half the L. parva, and chironomidae larvae. Chironomids were 47% of the total food and were found in 27% of the tracts analyzed. Other materials such as amphipod tubes, fish eggs, and sand were present in low to moderate amounts.

B. Poecilia latipinna (LeSueur). Sailfin Molly.

The sailfin molly feeds largely upon vascular plant detritus, algae, and occasional microcrustaceans (Hiatt 1947, Hunt 1953, Springer and Woodburn 1960, Harrington and Harrington 1961, Odum 1971). One specimen was analyzed in the present study. Plant and bottom matter was contained in the gut.

C. Cyprinodon variegatus. Lacepede. Sheepshead Minnow.

The sheepshead minnow is a nonspecialized herbivore that feeds upon insects and crustacea occasionally (Hildebrand and Schroeder 1928, Reid 1954, Simpson and Gunter 1956, Springer and Woodburn 1960, Harrington and Harrington 1969, Odum 1971).

I analyzed 39 C. variegatus that contained food. Animal foods were exclusively benthic. The amphipod Corophium lacustre was most frequently utilized and comprised 48% of the total food. Harpacticoid copepods were 20% of the total food. Other animal foods such as bivalves and chironomids were numerically sparse. All tracts with food contained vegetable and/or detrital material. Algal and vascular vegetation was consumed.

D. Fundulus grandis Baird and Girard. Gulf Killifish.

The Gulf killifish is a nonspecialized predator that feeds mainly upon crustaceans, insects, and fishes (Simpson and Gunter 1956, Springer and Woodburn 1960, Harrington and Harrington 1961, Odum 1971, Diener et al. 1974).

In the current study, 84 killifish with food (17.8-96.9 mm) were analyzed. Foods were numerous and diverse. The diet, in terms both of taxonomic composition and habitat of food organisms, greatly resembled

that of _Menidia beryllina_. Feeding occurred on and in the substrate, in the water column, and at the surface. Figure 25 shows frequencies of major _F. grandis_ food groups. Amphipoda (_Corophium_, _Gammarus_, _Grandidierella_, _Melita_, and unidentifiables) dominated the food. They comprised 54% of the total food and occurred in more than 80% of the stomachs. Insecta were 41% of the total food and occurred in more than half the tracts. Ephemeroptera, Odonata, Hemiptera, Hymenoptera (terrestrial Formicidae), Coleoptera, Orthoptera, and Diptera were represented in the food. Organisms occurring in less than 20% of the stomachs included polychaetes, bivalves, gastropods, mysids, decapods, and fishes. The tanaidacean _Hargaria rapax_, nearly uniquely fed upon by _Menidia beryllina_, was eaten by two _F. grandis_. Identified food fishes were _Gobiosoma bosci_ and _Menidia beryllina_. Plant matter, sand, fish eggs, and other miscellaneous material were in approximately one-third of the stomachs.

Figure 26 shows growth-related food changes among 71 _F. grandis_ divided into four size classes. As was seen for _M. beryllina_, steady progressive trends with respect to habitat and/or size of prey were not as clear as those observed for more selective predators such as _Cynoscion_ spp. Amphipoda were important through all size classes and were consumed by 90% or more specimens in the two largest classes. Bivalvia appeared to slowly, steadily increase in the food as killifish grew, as did another mainly infaunal prey, Polychaeta. Hemiptera (primarily Corixidae) occurred in the smallest and largest size classes only and were over twice as commonly eaten among the largest _F. grandis_. Chironomidae larvae rapidly decreased between the first and third size classes but were unsteady because the largest size class showed a slight relative rise. Fishes were the steadiest food group and remained at less than

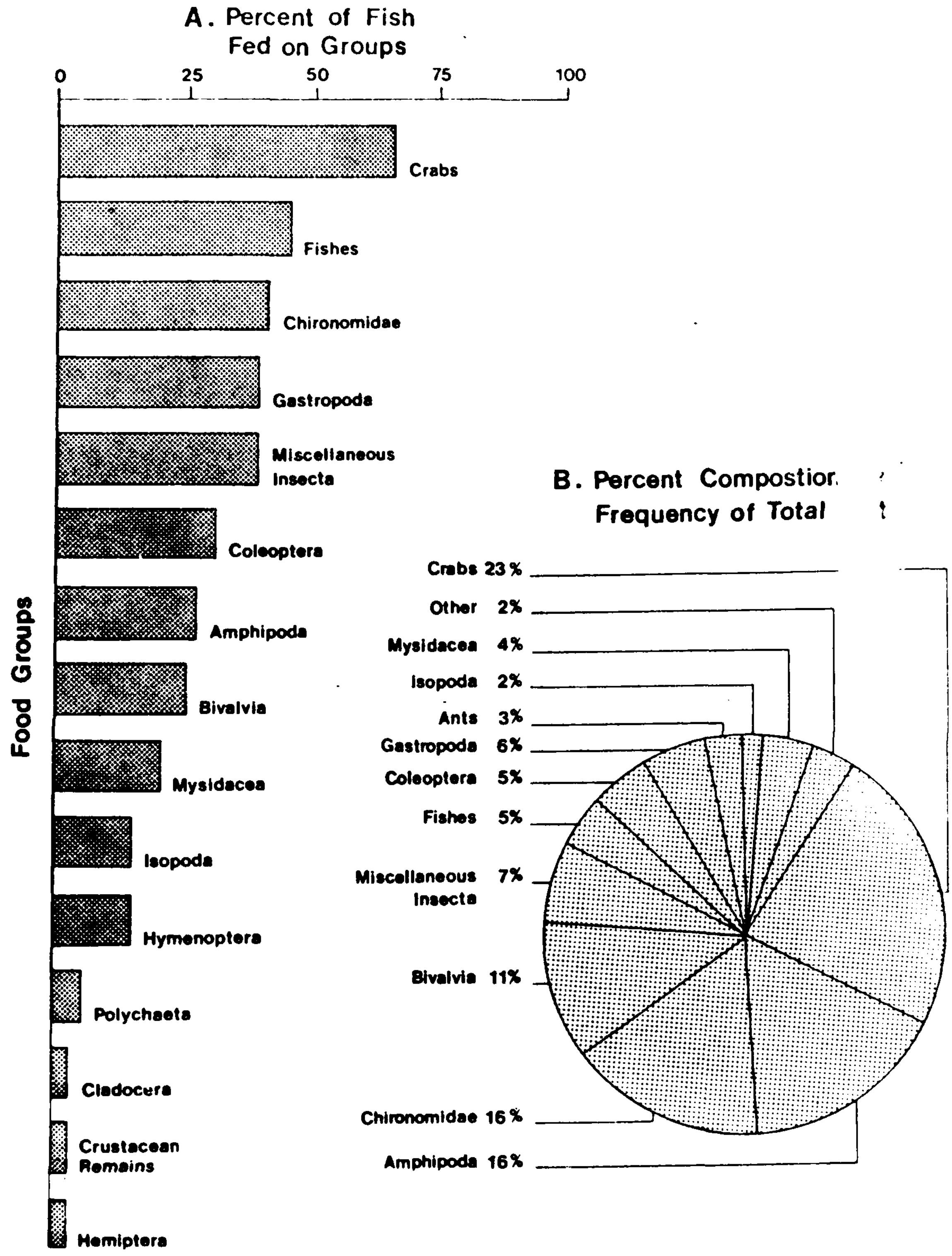


Figure 25. Percent of fish that consumed each food taxon (A) and percent frequency of foods (B) among Fundulus grandis from Lake Pontchartrain, LA, 1977-1978.

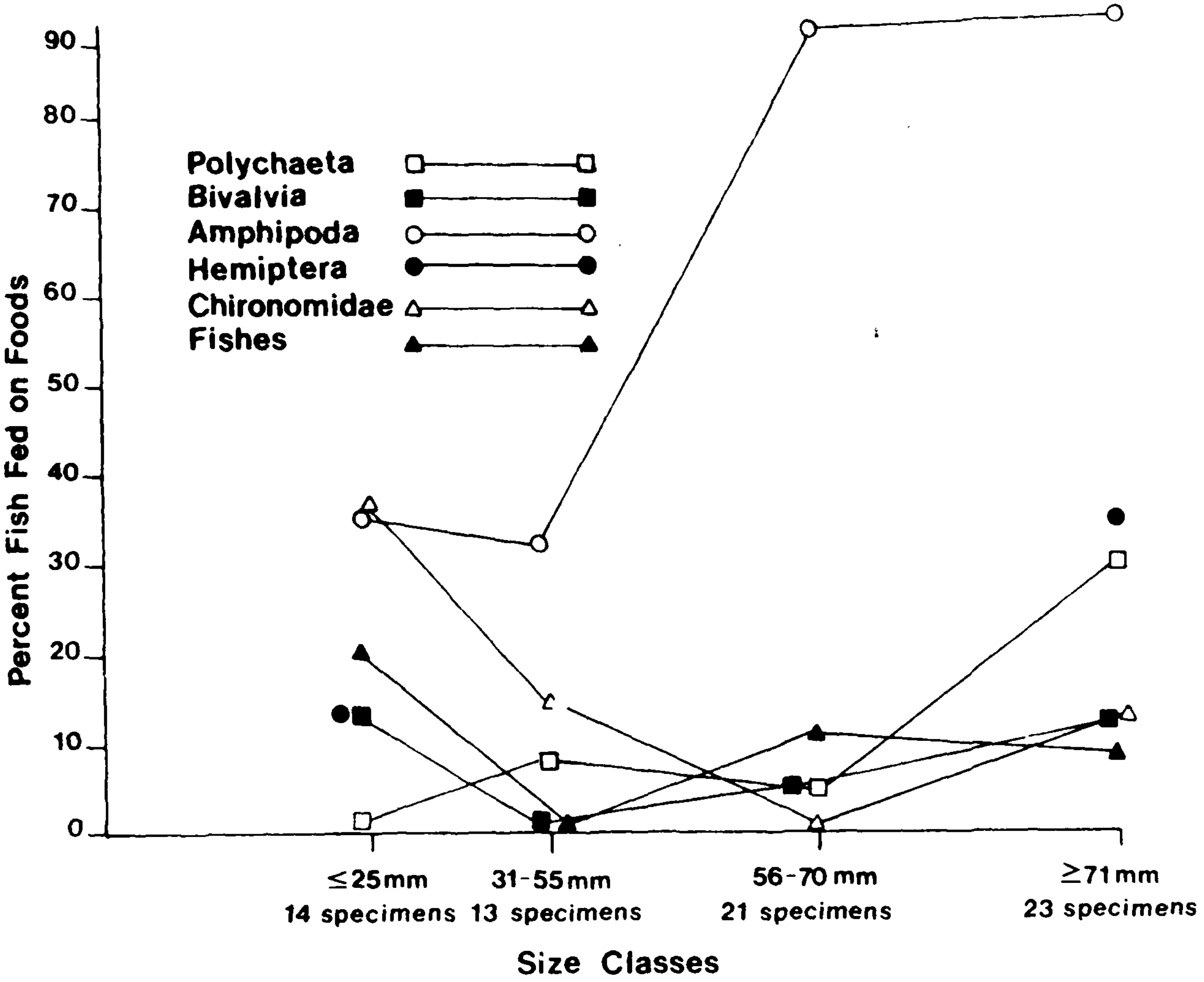


Figure 26. Growth-related food changes among Fundulus grandis from Lake Pontchartrain, LA, 1977-1978.

20% frequency through three of the four size classes. The most readily discernible trend in growth-related feeding was increased generalization with increased size of fish.

E. Fundulus similis (Baid and Girard). Longnose Killifish.

Diener et al. (1974) reported that two F. similis from Florida fed upon xanthid crabs. I examined three specimens, and none contained food.

XX. Centrarchidae

A. Micropterus salmoides (Lacepede). Largemouth Bass.

Food habits of the largemouth bass have been widely studied (Forbes 1888, Smith 1907, Hankinson 1908, Baker 1916, Pearse 1918, Forbes and Richardson 1920, Turner and Kraatz 1920, DeRyke and Scott 1922, Greeley 1927, Ewers and Boesel 1936, Cooper 1937, McCormick 1940, Howell et al. 1941, Nelson and Hasler 1942, Carr 1942, Dendy 1946, McClane 1948, Murphy 1949, Lambou 1952, Lewis et al. 1961, Kramer and Smith 1962, McCammon et al. 1964, Hodson and Strawn 1965, Rodgers 1968, Pasch 1972, Chew 1972, Elliot 1976, Levine 1977). The largemouth bass is an opportunistic predator progressing with growth from planktivory to microcrustacea and insects to a diet of fishes and larger crustaceans.

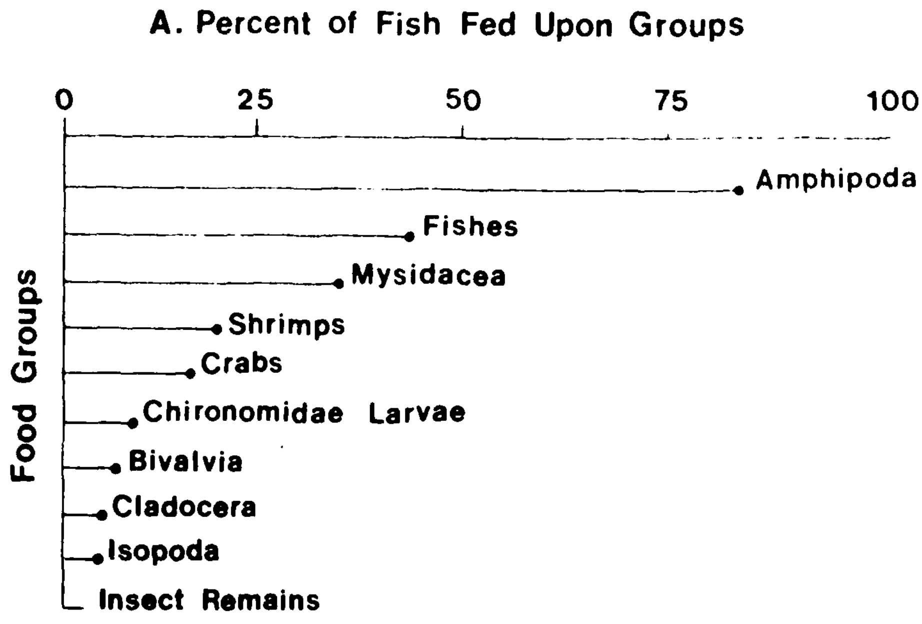
Darnell (1958) examined two M. salmoides (175-209 mm) with food from Lake Pontchartrain. Ninety-seven percent of the stomach contents was Decapoda (Palaemonetes spp. and Callinectes sapidus). In the present study, 35 bass (11-170 mm) with food were analyzed. Foods ranged from infaunal bivalves to corixid insects. Amphipoda (Corophium and Gammarus spp.) were the most important overall food. They occurred in more than 81% of the stomachs and comprised 17% of the total diet by frequency

(Fig. 27). Chironomid larvae were 58% of the total food but occurred in under 13% of the stomachs. Fishes (Menidia beryllina, Gobiosoma bosci, Syngnathus scovelli, Lepomis macrochirus, and unidentifiables) were 2% of the food but were eaten by nearly [illegible]% of the bass analyzed. Cladocera were 4% of the total food and occurred in 6% of the stomachs. Decapoda (Palaemonetes spp. and Rhithropanopeus harrisii) were of moderate importance as food. Insecta other than chironomids were not numerous but were diverse. Ephemeroptera, Hemiptera, and Orthoptera were observed in the food. Mysidacea occurred in 37.5% of the tracts. Taphromysis louisianae was the more numerous mysid species eaten and was indicative of feeding by bass in freshwater areas such as the Bayou Lacombe marsh and the mouth of Bayou St. John. Vegetable and miscellaneous matter, probably incidental, were present in small quantities.

Feeding among bass analyzed occurred throughout the water column, although active organisms seemed especially selected. McClane (1948), Kramer and Smith (1962), and Elliot (1976) noted that M. salmoides of all sizes seldom attacked a motionless organism. Chironomidae larvae often are vertically migrating meroplankters that are neither motionless or elusive. As was seen in the present study, periods of heavy migration of these insect larvae would result in substantial predation upon them by bass. Young M. salmoides share habitat and food preference with Menidia beryllina and Fundulus grandis.

B. Lepomis punctatus (Valenciennes). Spotted Sunfish.

Hunt (1953) and Odum (1971) described the spotted sunfish as carnivorous upon microcrustacea, small mollusks, crabs, and insects. I analyzed 19 specimens (31-120 mm). The primary food was Crustacea, which were 88% of the total food and occurred in 94.7% of the tracts.



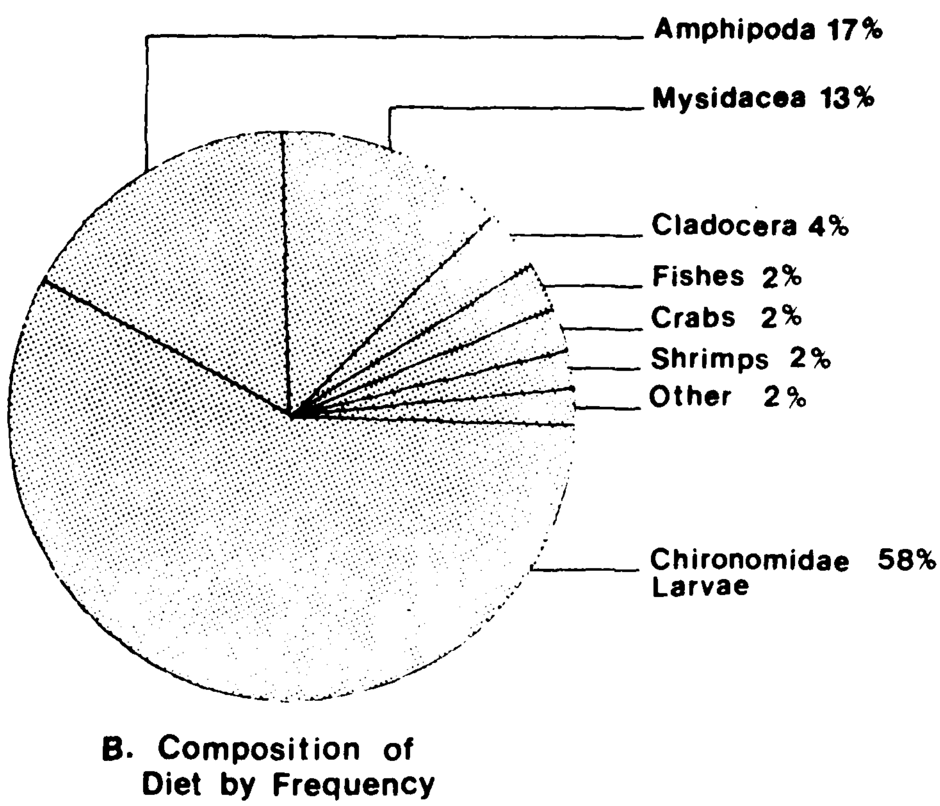


Figure 27. Percent of fish that consumed each food taxon (A) and percent frequency of foods (B) among Micropterus salmoides from Lake Pontchartrain, LA, 1977-1978.

Isopoda, Tanaidacea, Amphipoda (Corophium and Gammarus spp.), and Decapoda comprised the crustacean fraction. Four insect orders entered the food (Ephemeroptera, Odonata, Hymenoptera, and Diptera). Insects were 8% of the total food and occurred in 37% of the stomachs. Vegetable and other matter occurred in roughly half the stomachs. Mollusks were 4% of the total food. Feeding in spotted sunfish was mainly substrate oriented; opportunism was shown by consumption of terrestrial insects (ants).

C. Lepomis macrochirus Rafinesque. Bluegill Sunfish.

The bluegill in freshwater is a generalized feeder that consumes chrionomid larvae, amphipods and isopods, molluscs, insects, fishes, and plant material (Moffett and Hunt 1945, Ball 1948, Gerking 1952, Seaburg and Moyle 1963, Keast 1965, Keast and Webb 1966, Kitchell and Windell 1970). Desselle et al. (1978) reported feeding of L. macrochirus and other sunfishes in the Lake Pontchartrain estuary and noted apparent interspecific feeding niche segregation. Sunfishes are niche flexible and are able to utilize diverse, even marginal, habitats (Desselle et al. op. cit.).

In the current study, 15 bluegills (39-143 mm) were analyzed. Congeria leucophaeta and other mollusks were 2.6% of the total food and occurred in one-third of the stomachs. Crustacea were numerous and diverse in the food; they comprised 68.3% of the total diet and occurred in 66.7% of the stomachs. Copepoda and Amphipoda (Corophium and Gammarus spp.) were the primary crustacean food groups. Insects were a small (28.9%) fraction of the total food but occurred in more than 73.3% of the stomachs. Nearly all insect remains were chironomidae larvae. One fish, Gobiosoma bosci, entered the food. In contrast to many other studies, vegetable matter was present in just one stomach of the 15 that contained food.

D. Lepomis microlophus (Gunther). Redear Sunfish.

Lepomis microlophus in fresh water is characterized as feeding primarily upon gastropods (Huish 1957, Pflieger 1975, Bryan et al. 1975). I analyzed seven redear sunfish (44.5-179 mm). Their diet was more diverse than literature indicated. Worms were 2.9% of the total food and were in 29% of the stomachs. Bivalve mollusks were 54% of the total food and occurred in 28.6% of the stomachs. Crustacea (Corophium spp. amphipods, the isopod Cyathura polita) were 34% of the total diet and were consumed by 86% of the redears. Forty-three percent of the stomachs contained Chironomidae larvae, and vegetable material was found in 14%. Lepomis microlophus was the most substrate-oriented feeder of the sunfishes analyzed in this report. Its primary reliance upon bivalves removed it from competitive pressures from syntopic Lepomis spp. fishes, none of which fed as heavily upon Bivalvia.

DISCUSSION

Darnell (1958) wrote that his food studies revealed two main food chains within Lake Pontchartrain. The first chain proceeded from copepods (he specifically named Acartia spp.) through small fishes such as anchovies, menhaden, and young sciaenids to larger predators. The second chain involved small benthic invertebrates, larger invertebrates, through small benthic fishes, to "the same large predators". Detritus was emphasized throughout Darnell's work as prominent in the food of many fish and invertebrate species and as "an important source of nutrition for the copepods and small benthic invertebrates ...."

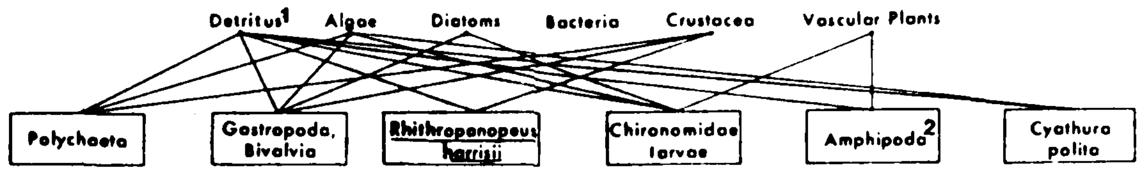
I believe that Darnell's presentation of Lake Pontchartrain's trophic pathways is essentially valid, but he was incorrect in proposing that the role of detritus is paramount in the lake's food web. Darnell

recognized and properly labeled estuaries as "open systems" because they provide allochtonous material in support of food organisms, and he also realized that feeding of fishes within such a system seldom is confined to discrete trophic levels. Progressive feeding changes with growth of fishes often involve successive specialization upon widely different food taxa (Darnell 1961). Despite his recognition of the nonlinear nature of estuarine trophic paths, Darnell still referred to "food chains" as described. As shown in Figure 28, my research suggests two major prey-predator pathways. The first is based (from the standpoint of fish food) upon six major benthic and infaunal taxa: polychaete worms, mollusks, the xanthid crab *Rhithropanopeus harrisii*, chironomidae larvae, amphipods, and the isopod *Cyathura polita*. In the present study, each was fed upon by at least 10 fish species. The second pathway consists of major food taxa that were associated with the water column planktonically or nektonically: mysids, copepods, decapods, and fishes. No fewer than seven fish species per food taxon were included in the present study. These two major trophic patterns are similar to those described by Darnell (1958) but they are much broader and are not mutually exclusive. I include Chironomidae larvae and polychaetes, for example, in the benthic category because these organisms are highly substrate oriented. Both taxa are known to inhabit other niches, however. The planktonic/nektonic web was based more upon mysids than copepods, according to my research. Many of the copepods taken from stomachs were in fact benthic harpacticoids.

Darnell (1958) considered any organism containing more than 5% detritus in its gut to be a detritus consumer, and he lumped most amorphous organic-appearing material as "organic detritus". Cole (1975) defined

detritus as matter composed of planktogenic, pondweed, and allochthonous fragments, feces and an associated bacterial flora; particles derived from agitation of soluble organics (such as vascular plant matter) and an attached microflora, dissolved organic mixtures directly usable by some algae, and heterotrophic bacteria growing on silt particles. Detritus is vital to Lake Pontchartrain trophic processes because the Pontchartrain food web is composed largely of detritivores such as amphipods, mysids, polychaetes, and chironomid larvae. Relatively few species in the Lake Pontchartrain system are detritus consumers (as shown in Fig. 28). I support Odum's (1971) challenge to Darnell's assertions that detritus serves as the primary food for many fishes including the most carnivorous species. Among Pontchartrain fishes, Mugil cephalus and Brevoortia patronus are probably the only species that definitely derive nourishment from directly ingested detritus particles (as Odum [1971] asserted for these species from a Florida estuary). Species such as Cynoscion arenarius and Strongylura marina (claimed by Darnell to obtain nourishment from detritus) are not structurally adapted as detritus consumers. Their digestive tracts are short, straight tubes, not the long, complex structures characteristic of detritivores (such as Brevoortia spp.).

One of the objectives of this report was to utilize previous research within the Lake Pontchartrain ecosystem as a baseline to produce predictive information. Ecological notes with reference to the sparid fishes Archosargus probatocephalus (sheephead) and Lagodon rhomboides (pinfish) are relevant in this context. Both species were abundant and successful in Darnell's time and remain so today (unfortunately, neither is a major sport or commercial fish in Pontchartrain, and detailed population records are not available). These fishes may benefit from certain human



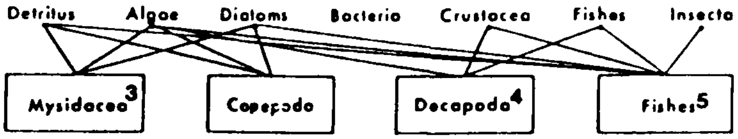
L. microlophus	L. parva	L. punctatus	L. microlophus	G. bosci	L. microlophus
L. rhomboides	A. mitchilli	M. salmoides	M. salmoides	L. parva	M. salmoides
M. beryllina	M. undulatus	M. undulatus	L. macrochirus	S. marina	M. beryllina
F. grandis	P. cromis	L. xanth s	L. punctatus	A. mitchilli	F. grandis
I. furcatus	A. probatocephalus	S. ocel	L. rhomboides	S. ocellata	I. furcatus
I. punctatus	L. xanthurus	L. rhomboides	A. probatocephalus	B. chrysura	I. punctatus
A. felis	G. strumosus	I. furcatus	M. beryllina	M. undulatus	A. felis
T. maculatus	A. felis	I. punctatus	F. grandis	L. xanthurus	T. maculatus
G. strumosus	I. furcatus	A. felis	C. variegatus	A. probatocephalus	L. xanthurus
L. xanthurus	F. grandis	G. strumosus	I. furcatus	T. maculatus	M. undulatus
M. undulatus	M. beryllina	G. bosci	I. punctatus	I. punctatus	B. marinas
B. chrysura	L. microlophus		A. felis	I. furcatus	G. bosci
A. mitchilli			T. maculatus	C. variegatus	
S. marina			L. xanthurus	F. grandis	
L. parva			M. undulatus	M. beryllina	
G. bosci			B. chrysura	L. rhomboides	
			L. parva	L. punctatus	
			G. bosci	L. macrolophus	
				M. salmoides	

[1] includes Protozoa, inorganics

[2] notably Corophium lacustre, Gammarus spp.

Figure 28. Trophic pathways of Lake Pontchartrain, LA, fishes.

Figure 28. (Continued)



E. saurus
P. octonemus
O. saurus
A. mitchilli
B. chrysura
C. nebulosus
C. arenarius
M. undulatus
L. xanthurus
I. furcatus
I. punctatus
A. felis
T. maculatus
M. beryllina
L. rhomboides
M. salmoides

A. mitchilli
M. undulatus
L. xanthurus
C. variegatus
G. affinis
M. beryllina
L. macrochirus

M. salmoides
L. punctatus
M. beryllina
I. furcatus
I. punctatus
A. felis
C. leucas
A. probatocephalus
M. undulatus
L. xanthurus
S. ocellata
B. marinus

G. bosci
B. marinus
A. felis
S. marina
S. ocellata
B. chrysura
C. nebulosus
C. arenarius
M. undulatus
L. xanthurus
G. strumosus
A. probatocephalus
I. punctatus
I. furcatus
M. beryllina
F. grandis
P. lethostigma
C. leucas
E. saurus
L. macrochirus
M. salmoides

[3] *Mysidopsis almyra* primarily

[4] *Palaemonetes* spp., *C. sapidus* primarily

[5] *Anchoa mitchilli*, *Gobiosoma bosci*, others

activities because of their generalized diet and ability to feed effectively over hard substrates. Hard substrates are already plentiful, e.g., the Causeway and other bridges, power line foundations, and the New Orleans seawall. Further installation of hard substrate zones could upset the ecology of the lake because sparid fishes might be benefited in a manner possibly out of balance with other fishes. Other fish species are also generalists but are not so facultative in feeding habit as Sparidae.

As discussed by Thompson and Verret (Chapter 12), beds of rooted aquatic vegetation are crucial nurseries for many fish species, including some of the commercially important sciaenids. The "grassbeds" support tremendous numbers of detritivorous invertebrates that are primary foods for many Lake Pontchartrain fishes. Even the highly artificial urban habitat at the mouth of Bayou St. John on the New Orleans lakefront supports abundant, diverse fish populations, perhaps because of the rich beds of Vallisneria spp. and other plants found there.

Other major food sources for Lake Pontchartrain fishes are the enormous bivalve and gastropod populations. Catfishes, spot, and croaker are among the fish species heavily dependent upon mollusks for food. Available, easily preyed-upon mollusks provide an important buffer for interspecific competition; even the largest blue catfish we captured had fed heavily upon bivalves rather than more elusive fishes and macrocrustaceans that were highly sought after by other predators such as trout and ladyfish. My food data seem to show higher dependence, particularly by catfish and anchovies, upon mollusks than did Darnell's. Sight feeding may now be hindered by higher turbidities, and predation upon bivalves may only be now accomplished without visual cues.

Lake Pontchartrain is an open system where there is little rigid segregation of niches among fishes. In response, feeding by fishes has probably become quite generalized and opportunistic. I believe that opportunism in feeding can persist among large, diverse fish populations only if food sources are also large and diverse. I also believe that changes in the environment between the time of Darnell and the present have been primarily man induced (such as shell dredging and draining of wetlands) and have been in the direction of greater simplification of the Lake Pontchartrain ecosystem.

Camp and associated paraphernalia on southwest shore of Lake Pontchartrain

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APPENDIX

DATA ON GUT CONTENTS IN TABULAR FORM

Elops saurus - Ladyfish
No. with food: 11

Food Taxa	No.	% Total	No. Fish Fed on Item*	% Total*
Crustacea				
Mysidacea				
Mysidopsis almyra	1732	99.31	4	36.36
Pisces				
Anchoa mitchilli	1	0.06	1	9.09
Menidia beryllina	2	0.12	1	9.09
Micropogonias undulatus	1	0.06	1	9.09
Poecilia latipinna	1	0.06	1	9.09
Unid. remains	7	0.40	6	54.55
TOTAL PISCES	12	0.69		
Other				
Unrecog. material			1	9.09
Bottom material			1	9.09
TOTAL	1744	100.00		

*Non-additive.

Strongylura marina - Atlantic Needlefish
No. with food: 34

Food Taxa	No.	% Total	No. Fish Fed on Item*	% Total*
Nereidae remains	4	4.08	2	5.88
Crustacea				
Unid. remains	2	2.04	2	5.88
Tanaidacea				
Hargaria rapax	1	1.02	1	2.94
Amphipoda				
Corophium lacustre	25	25.51	3	8.82
Unid. remains	1	1.02	1	2.94
TOTAL CRUSTACEA	29	29.59		
Insecta				
Odonata	1	1.02	1	2.94
Hemiptera				
Corixidae	1	1.02	1	2.94
Hymenoptera				
Formicidae	1	1.02	1	2.94
Unid. remains	2	2.04	1	2.94
Diptera				
Chironomidae larvae	10	10.20	3	8.82
Pupae	12	12.24	4	11.76
Unid. remains	9	9.18	5	14.71
Insect remains	5	5.10	3	8.82
TOTAL INSECTA	41	41.84		
Pisces				
Anchoa mitchilli	20	20.41	14	41.18
Unid. remains	4	4.08	4	11.76
TOTAL PISCES	24	24.49		
Other				
Unrecog. material	—	—	4	11.76
TOTAL	98	100.00		

*Non-additive.

Anchoa mitchilli - Bay Anchovy
No. with food: 40

Food Taxa	No.	% Total	No. Fish Fed on Item*	% Total*
Polychaeta				
Laeonereis culveri	50	15.67	1	2.50
Oligochaeta	1	0.31	1	2.50
Mollusca				
Bivalvia				
Macoma mitchilli	1	0.31	1	2.50
Unid. remains	77	24.14	16	40.00
TOTAL MOLLUSCA	78	24.45		
Crustacea				
Copepoda				
Harpacticoida	1	0.31	1	2.50
Calanoida	22	6.90	6	15.00
Cyclopoida	1	0.31	1	2.50
Unid. remains	128	40.13	12	30.00
Amphipoda				
Gammarus tigrinus	1	0.31	1	2.50
Cerapus spp.	12	3.76	1	2.50
Mysidacea				
Mysidopsis almyra	20	6.27	7	17.50
Unid. remains	3	0.94	1	2.50
TOTAL CRUSTACEA	188	58.93		
Insecta				
Hemiptera				
Corixidae	1	0.31	1	2.50
Diptera				
Chironomidae larvae	1	0.31	1	2.50
Other				
Unrecog. material			5	12.50
Fish eggs			1	2.50
Sand			4	10.00
TOTAL	319	100.00		

*Non-additive.

Sciaenops ocellata - Redfish
No. with food: 19

Food Taxa	No.	% Total	No. Fish Fed on Item*	% Total*
Crustacea				
Amphipoda				
Corophium spp. remains	1	2.17	1	5.26
Gammarus tigrinus	2	4.35	1	5.26
Unid. remains	13	28.26	2	10.53
Decapoda				
Macrobrachium ohione	2	4.35	1	5.26
Palaemonetes spp.	2	4.35	1	5.26
Callinectes sapidus	7	15.22	6	31.58
Rhithropanopeus harrisii	2	4.35	2	10.53
CRUSTACEA TOTAL	29	63.04		
Insecta				
Unid. remains	1	2.17	1	5.26
Pisces				
Brevoortia patronus	1	2.17	1	5.26
Micropogonias undulatus	1	2.17	1	5.26
Alosa chrysochloris	1	2.17	1	5.26
Unid. remains	13	28.26	8	42.11
TOTAL PISCES	16	34.78		
Other				
Vegetable material			1	5.26
Unrecog. material	—	—	4	21.05
TOTAL	46	100.00		

*Non-additive.

Bairdiella chrysura - Silver Perch
No. with food: 14

Food Taxa	No.	% Total	No. Fish Fed on Item*	% Total*
Nereidae remains	1	0.43	1	7.14
Crustacea				
Unid. remains	2	0.87	1	7.14
Isopoda	1	0.43	1	7.14
Amphipoda				
Corophium spp. remains	1	0.43	1	0.43
Gammarus "macromucronatus"	3	1.30	2	14.29
Gammarus spp. remains	4	1.73	3	21.43
Unid. remains	3	1.30	2	14.29
Mysidacea				
Mysidopsis almyra	207	89.61	4	28.57
Unid. remains	3	1.30	3	21.43
Decapoda				
Shrimp remains	1	0.43	1	7.14
TOTAL CRUSTACEA	225	97.40		
Insecta				
Diptera				
Chironomidae larvae	3	1.30	3	21.43
Unid. remains	1	0.43	1	7.14
Pisces				
Unid. remains	1	0.43	1	7.14
TOTAL	231	100.00		

*Non-additive.

Cynoscion arenarius - Sand Seatrout
No. with food: 109

Food Taxa	No.	% Total	No. Fish Fed on Item*	% Total*
Mollusca				
Gastropoda				
Texadina sphinctosoma	1	0.08	1	0.92
Unid. remains	1	0.08	1	0.92
Crustacea				
Amphipoda				
Corophium lacustre	1	0.08	1	0.92
Gammarus mucronatus	1	0.08	1	0.92
Gammarus tigrinus	1	0.08	1	0.92
Gammarus spp. remains	1	0.08	1	0.92
Mysidacea				
Mysidopsis almyra	1063	83.13	47	43.12
Taphromysis louisianae	21	1.64	1	0.92
Unid. remains	128	10.02	16	14.68
TOTAL CRUSTACEA	1216	95.14		
Pisces				
Anchoa mitchilli	5	0.40	4	3.67
Myrophis punctatus	1	0.08	1	0.92
Elops saurus	1	0.08	1	0.92
Membras martinica	1	0.08	1	0.92
Unid. remains	52	4.07	43	39.45
TOTAL PISCES	60	4.69		
Other				
Vegetable material			1	0.92
Amorphous material			9	8.26
TOTAL	1278	100.00		

*Non-additive.

Cynoscion nebulosus - Spotted Seatrout
No. with food: 32

Food Taxa	No.	% Total	No. Fish Fed on Item*	% Total*
Crustacea				
Amphipoda				
Gammarus mucronatus	4	0.90	2	6.25
Gammarus spp. remains	1	0.22	1	3.13
Unid. remains	3	0.67	1	3.13
Mysidacea				
Mysidopsis almyra	370	82.96	12	37.50
Taphromysis louisianae	44	9.87	3	9.38
Decapoda	1	0.22	1	3.13
TOTAL CRUSTACEA	423	94.84		
Insecta				
Diptera				
Chironomidae larvae	1	0.22	1	3.13
Pisces				
Brevoortia patronus	2	0.45	2	6.25
Micropogonias undulatus	3	0.67	3	9.38
Gobiosoma bosci	1	0.22	1	3.13
Dorosoma spp.	1	0.22	1	3.13
Mugil cephalus	1	0.22	1	3.13
Unid. remains	14	3.14	14	43.75
TOTAL PISCES	23	5.16		
Other				
Vegetable material			1	3.13
Amorphous material			1	3.13
TOTAL	446	100.00		

*Non-additive.

Micropogonias undulatus - Atlantic Croaker
No. with food: 277

Food Taxa	No.	% Total	No. Fish Fed on Item*	% Total*
Nereidae remains	44	1.41	41	14.80
Oligochaeta remains	7	0.22	7	2.53
Mollusca				
Gastropoda				
Probythinella protera	2	0.06	2	0.72
Texadina sphinctosoma	6	0.19	4	1.44
Unid. remains	8	0.26	6	2.17
Bivalvia				
Congeria leucophaeta	75	2.41	33	11.91
Macoma mitchilli	13	0.42	2	0.72
Rangia cuneata	120	3.85	37	13.36
Unid. remains	39	1.25	12	4.33
TOTAL MOLLUSCA	263	8.44		
Crustacea				
Unid remains	6	0.19	6	2.17
Copepoda				
Harpacticoida	6	0.19	3	1.08
Calanoida	1277	40.98	16	5.78
Unid. remains	173	5.55	13	4.69
Isopoda				
Cyathura polita	13	0.42	10	3.61
Edotea montosa	4	0.13	4	1.44
Unid. remains	34	1.09	6	2.17
Amphipoda				
Corophium lacustre	33	1.06	9	3.25
Corophium spp. remains	18	0.58	11	3.97
Gammarus tigrinus	133	4.27	4	1.44
Gammarus spp. remains	7	0.22	7	2.53
Grandidierella bonneroides	12	0.38	5	1.81
Unid. remains	37	1.88	21	7.58
Mysidacea				
Mysidopsis almyra	484	15.53	66	23.83
Mysidacea remains	130	4.17	29	10.47
Decapoda				
Palaemonetes spp.	1	0.03	1	0.36
Callianassa jamaicense	1	0.03	1	0.36
Rhithropanopeus harrisii	46	1.47	24	8.66
Crab remains	7	0.22	5	1.80
TOTAL CRUSTACEA	2422	77.73		
Insecta				
Hemiptera	10	0.32	1	0.36
Coleoptera				
Dytiscidae	1	0.03	1	0.36

*Non-additive.

Micropogonias undulatus - (Continued)

Food Taxa	No.	% Total	No. Fish Fed on Item*	% Total*
Diptera				
Chironomidae larvae	283	9.08	81	29.24
Ceratopogonidae larvae	3	0.10	1	0.36
Pupae	3	0.10	2	0.72
Thysanoptera	2	0.06	2	0.72
Psocoptera	1	0.03	1	0.36
Insect remains	3	0.03	1	0.36
TOTAL INSECTA	306	9.82		
Pisces				
Anchoa mitchilli	5	0.16	4	1.44
Unid. remains	16	0.51	16	5.78
Other				
Vegetable material			6	2.17
Unrecog. material			63	22.74
Fish eggs			1	0.36
Sand			16	5.78
Bottom material			27	9.75
Amphipod tubes			1	0.36
TOTAL	3116	100.0		

*Non-additive.

Leiostomus xanthurus - Spot
No. wih food: 197

Food Taxa	No.	% Total	No. Fish Fed on Item*	Total*
Nereidae remains	21	0.09	8	4.06
Oligochaeta	33	0.14	19	9.64
Mollusca				
Gastropoda				
Probythinella protera	20	0.08	5	2.54
Texadina sphinctosoma	13	0.05	6	3.05
Hydrobiid remains	1713	7.20	42	21.32
Bivalvia				
Congeria leucophaeta	18	0.08	8	4.06
Ischadium recurvus	2	0.01	1	0.51
Macoma mitchilli	248	1.04	23	11.68
Rangia cuneata	4197	17.63	16	8.12
Mulinia pontchartrainensis	144	0.61	6	3.05
Unid. remains	1881	7.90	72	36.55
TOTAL MOLLUSCA	8236	34.60		
Crustacea				
Unid. remains	76	0.32	11	5.58
Cladocera	508	2.13	20	10.15
Ostracoda	117	0.49	7	3.55
Copepoda				
Harpacticoida	1295	5.44	23	11.68
Calanoida	304	1.28	11	5.58
Cyclopoida	1	<0.01	1	0.51
Unid. remains	12048	50.82	62	31.47
Isopoda				
Cyathura polita	10	0.04	3	1.52
Edotea montosa	38	0.16	26	13.20
Unid. remains	11	0.05	5	2.54
Tanaidacea				
Hargaria rapax	1	<0.01	1	0.51
Amphipoda				
Monoculodes edwardsi	NA	NA	10	5.08
Corophium lacustre	87	0.37	13	6.60
Corophium spp. remains	10	0.04	6	3.05
Gammarus "macromucronatus"	5	0.02	3	1.52
Gammarus mucronatus	5	0.02	3	0.51
Gammarus tigrinus	1	<0.01	1	0.51
Gammarus spp. remains	2	<0.01	1	0.51
Grandidierella bonneroides	21	0.08	7	3.55
Melita spp.	2	<0.01	1	0.51
Unid. remains	69	0.29	15	7.61
Mysidacea				
Mysidopsis almyra	14	0.06	3	1.52
Unid. remains	11	0.05	2	1.02

*Non-additive.

Leiostomus xanthurus - (Continued)

Food Taxa	No.	% Total	No. Fish Fed on Item*	% Total*
Decapoda				
Callinectes sapidus	1	<0.01	1	0.51
Rhithropanopeus harrisii	5	0.02	3	1.52
TOTAL CRUSTACEA	14641	61.51		
Araneae	2	<0.01	2	1.02
Nematoda	189	0.79	26	13.20
Insecta				
Diptera				
Chironomidae larvae	519	2.18	78	39.59
Ceratopogonidae larvae	2	<0.01	2	1.02
Pupae	6	0.03	5	2.54
Unid. remains	2	<0.01	2	1.02
TOTAL INSECTA	529	2.22		
Pisces remains	1	<0.01	1	0.51
Other				
Vegetable material			41	20.81
Unrecog. material			49	24.87
Fish eggs			4	2.03
Shell fragments			26	13.20
Sand			61	30.96
Amphipod tubes			9	4.57
TOTAL	23801	100.00		

*Non-additive.

Archosargus probatocephalus - Sheepshead
No. with food: 6

Food Taxa	No.	% Total	No. Fish Fed on Item*	% Total*
Mollusca				
Gastropoda remains	15	31.91	2	33.33
Bivalvia				
Rangia cuneata	1	2.13	1	16.67
Unid. remains	5	10.64	1	16.67
TOTAL MOLLUSCA	21	44.68		
Crustacea				
Amphipoda				
Gammarus tigrinus	22	46.81	1	16.67
Decapoda				
Callinectes sapidus	2	4.26	2	33.33
TOTAL CRUSTACEA	24	51.06		
Insecta				
Diptera				
Chironomidae larvae	1	2.13	1	16.67
Pisces				
Unid. remains	1	2.13	1	16.67
Other				
Amorphous material			3	50.00
Amphipod tubes	—	—	1	16.67
TOTAL	47	100.00		

*Non-additive.

Lagodon rhomboides - Pinfish
No. with food: 14

Food Taxa	No.	% Total	No. Fish Fed on Item*	% Total*
Nereidae remains	2	1.19	2	14.29
Crustacea				
Unid. remains	1	0.60	1	7.14
Amphipoda				
Gammarus "macromucronatus"	2	1.19	1	7.14
Gammarus mucronatus	13	7.74	3	21.43
Gammarus spp. remains	3	1.79	3	21.43
Unid. remains	11	6.55	4	28.57
Mysidacea				
Mysidopsis almyra	126	75.00	5	35.71
Unid. remains	1	0.60	1	7.14
Decapoda				
Rhithropanopeus harrisii	2	1.19	1	7.14
Crab remains	2	1.19	2	14.29
TOTAL CRUSTACEA	161	95.83		
Insecta				
Diptera				
Chironomidae larvae	3	1.79	2	14.29
Pupae	1	0.59	1	7.14
Insect remains	1	0.59	1	7.14
Other				
Vegetable material			9	64.29
Amorphous material			3	21.43
Fish eggs			1	7.14
Sand			2	14.29
TOTAL	168	100.00		

*Non-additive.

Trinectes maculatus - Hogchoker
No. with food: 69

Food Taxa	No.	% Total	No. Fish Fed on Item*	% Total*
Polychaeta				
Nereidae remains	17	4.14	15	21.74
Mollusca				
Congeria leucophaeta	2	0.49		
Rangia cuneata	1	0.24	1	1.45
Crustacea				
Unid. remains	1	0.24	1	1.45
Copepoda				
Calanoida	4	0.97	1	1.45
Unid. remains	4	0.97	2	2.90
Isopoda				
Cyathura polita	7	1.71	4	5.80
Amphipoda				
Corophium remains	12	2.92	5	7.25
Unid. remains	14	3.41	6	8.70
Mysidacea				
Taphromysis louisianae	1	0.24	1	1.45
Unid. remains	7	1.70	4	5.80
Decapoda				
Rhithropanopeus harrisii	1	0.24	1	1.45
TOTAL CRUSTACEA	51	12.41		
Insecta				
Diptera				
Chironomidae larvae	335	81.51	36	52.17
Diptera	1	0.24	1	1.45
Insect remains	4	0.97	4	5.80
Other				
Unrecog. material			10	14.49
Sand			15	21.74
Amphipod tubes			1	1.45
TOTAL	411	100.00		

*Non-additive.

Gobiosoma bosci - Naked Goby
No. with food: 53

Food Taxa	No.	% Total	No. Fish Fed on Item*	% Total*
Polychaeta				
Laeonereis culveri	1	0.75	1	1.89
Nereidae remains	8	6.02	8	15.09
Crustacea				
Unid. remains	4	3.01	4	7.55
Ostracoda	2	1.50	1	1.89
Copepoda				
Cyclopoida	2	1.50	1	1.89
Isopoda				
Cyathura polita	2	1.50	1	1.89
Unid. remains	4	3.01	3	5.66
Tanaidacea				
Hargaria rapax	11	8.27	4	7.55
Amphipoda				
Corophium lacustre	4	3.01	4	7.55
Corophium louisianum	4	3.01	2	3.77
Corophium spp. remains	4	3.01	2	3.77
Gammarus "macromucronatus"	3	2.56	3	5.66
Gammarus mucronatus	10	7.52	6	11.32
Gammarus tigrinus	2	1.50	2	3.77
Gammarus spp. remains	16	12.03	8	15.09
Grandidierella bonneroides	1	0.75	1	1.89
Cerapus spp.	8	6.02	3	5.66
Unid. remains	27	20.30	16	30.19
Decapoda				
Rhithropanopeus harrisii	2	1.50	1	1.89
TOTAL CRUSTACEA	106	79.70		
Araneae	1	0.75	1	1.89
Insecta				
Diptera				
Chironomidae	14	10.53	11	20.75
Insect remains	1	0.75	1	1.89
Pisces				
Anchoa mitchilli	1	0.75	1	1.89
Unid. remains	1	0.75	1	1.89
Other				
Unrecog. material			10	18.87
Sand			16	30.19
TOTAL	133	100.00		

*Non-additive.

Gobiesox strumosus - Skilletfish
No. with food: 34

Food Taxa	No.	% Total	No. Fish Fed on Item*	% Total*
Nereidae remains	1	0.34	1	2.94
Mollusca				
Bivalvia remains	12	4.08	3	8.82
Crustacea				
Isopoda	8	2.72	3	8.82
Amphipoda				
Corophium lacustre	4	1.36	3	8.82
Corophium spp. remains	4	1.36	3	8.82
Gammarus "macromucronatus"	35	11.91	13	38.24
Gammarus mucronatus	116	39.46	17	50.00
Gammarus spp. remains	2	0.68	2	5.88
Melita spp.	1	0.34	1	2.94
Unid. remains	11	3.74	8	23.53
Mysidacea	1	0.34	1	2.94
Decapoda				
Palaemonetes spp.	7	2.38	6	17.65
Rhithropanopeus harrisii	4	1.36	4	11.76
Crab remains	1	0.34	1	2.94
TOTAL CRUSTACEA	194	65.98		
Insecta				
Diptera				
Chironomidae larvae	23	7.82	10	29.41
Pupae	62	21.09	1	2.94
Unid. remains	1	0.34	1	2.94
TOTAL INSECTA	86	29.25		
Pisces				
Gobiosoma bosci	1	0.34	1	2.94
Other				
Unrecog. material			1	2.94
Sand			1	2.94
TOTAL	294	100.00		

*Non-additive.

Bagre marinus - Gafftopsail Catfish
No. with food: 10

Food Taxa	No.	% Total	No. Fish Fed on Item*	% Total*
Crustacea				
Isopoda				
Cyathura polita	1	7.69	1	10.00
Decapoda				
Penaeus spp.	1	7.69	1	10.00
Callinectes sapidus	3	23.08	2	20.00
Pisces				
Micropogonias undulatus	1	7.69	1	10.00
Unid. remains	7	53.85	5	50.00
Other				
Unrec. material			1	10.00
TOTAL	13	100.00		

*Non-additive.

Arius felis - Hardhead Catfish
No. with food: 34

Food Taxa	No.	% Total	No. Fish Fed on Item*	% Total*
Nereidae	2	0.57	2	5.88
Mollusca				
Gastropoda				
Texadina sphinctosoma	10	2.86	8	23.53
Unid. remains	7	2.00	3	8.82
Bivalvia				
Congeria leucophaeta	32	9.14	4	11.76
Rangia cuneata	1	0.29	1	2.94
Unid. remains	2	0.57	2	5.88
TOTAL MOLLUSCA	52	14.86		
Crustacea				
Unid. remains	1	0.29	1	2.94
Cladocera	1	0.29	1	2.94
Isopoda				
Cyathura polita	4	1.14	3	8.82
Unid. remains	1	0.29	1	2.94
Amphipoda				
Corophium lacustre	43	12.29	2	5.88
Gammarus tigrinus	5	1.43	3	8.82
Hyalella azteca	2	0.57	2	5.88
Melita spp.	1	0.29	1	2.94
Mysidacea				
Mysidopsis almyra	4	1.14	3	8.82
Mysid remains	9	2.57	3	8.82
Decapoda				
Callinectes sapidus	7	2.00	7	20.59
Rhithropanopeus harrisii	63	18.00	11	32.35
Crab remains	1	0.29	1	2.94
TOTAL CRUSTACEA	142	40.57		
Insecta				
Odonata				
Lestes spp.	1	0.29	1	2.94
Odonata remains	1	0.29	1	2.94
Hemiptera				
Belostoma spp.	2	0.57	1	2.94
Hymenoptera				
Formicidae	3	0.86	1	2.94
Unid. remains	6	1.71	3	8.82
Coleoptera				
Hydrophilidae	4	1.14	2	5.88
Dytiscidae	7	2.00	4	11.76
Unid. remains	4	1.14	3	2.94
Orthoptera	2	0.57	2	5.88

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Arius felis - (Continued)

Food Taxa	No.	% Total	No. Fish Fed on Item*	% Total*
Diptera				
Chironomidae larvae	49	14.00	12	35.29
Ceratopogonidae larvae	4	1.14	1	2.94
Stratiomyiidae larvae	2	0.57	2	5.88
Diptera pupae	32	9.14	4	11.76
Insect remains	21	6.00	11	32.35
TOTAL INSECTA	138	39.43		
Pisces				
Brevoortia patronus	7	2.00	4	11.76
Dorosoma spp.	1	0.29	1	2.94
Unid. remains	8	2.20	8	23.53
TOTAL PISCES	16	4.57		
Other				
Vegetable material			8	23.53
Amorphous material			8	23.53
Fish eggs			4	11.76
Sand			1	2.94
Fish scales			3	8.82
TOTAL	350	100.00		

*Non-additive.

Ictalurus furcatus - Blue Catfish
No. with food: 112

Food Taxa	No.	% Total	No. Fish Fed on Item*	% Total*
Nereidae remains	8	0.14	6	9.68
Oligochaeta	10	0.17	8	7.14
Mollusca				
Gastropoda				
Probythinella protera	19	0.33	2	1.79
Texadina sphinctosoma	8	0.14	1	0.89
Unidentified remains	22	0.38	4	3.57
Bivalvia				
Congeria leucophaeta	129	2.25	9	8.04
Ischadium recurvus	4	0.07	3	2.68
Macoma mitchilli	1456	25.40	28	25.00
Rangia cuneata	1528	26.66	31	27.68
Mulinia pontchartrainensis	25	0.44	12	10.71
Unidentified remains	1120	19.54	NA	NA
TOTAL MOLLUSCA	4311	75.21		
Crustacea				
Unidentified remains	2	0.04	1	0.89
Copepoda	1	0.02	1	0.89
Isopoda				
Cyathura polita	19	0.33	2	1.79
Edotea montosa	289	5.04	12	10.91
Unid. remains	410	7.15	9	8.04
Amphipoda				
Corophium lacustre	19	0.33	10	8.93
Corophium spp. remains	47	0.82	15	13.40
Gammarus tigrinus	4	0.07	2	1.79
Gammarus spp. remains	20	0.35	7	6.25
Grandidierella bonneroides	17	0.30	6	5.36
Unid. remains	8	0.14	4	3.57
Mysidacea				
Mysidopsis almyra	10	0.17	5	4.46
Unid. remains	8	0.14	6	5.36
Decapoda				
Penaeus spp.	1	0.02	1	0.89
Callianassa jamaicense	1	0.02	1	0.89
Callinectes sapidus	5	0.09	4	3.57
Rhithropanopeus harrisii	15	0.26	11	9.82
Crab remains	21	0.37	3	2.68
Unid. remains	1	0.02	1	0.89
TOTAL CRUSTACEA	898	15.67		
Araneae	6	0.11	3	2.68
Nematoda	1	0.17	1	0.89

*Non-additive.

Ictalurus furcatus - (Continued)

Food Taxa	No.	% Total	No. Fish Fed on Item*	% Total*
Insecta				
Odonata				
Anisoptera	1	0.17	1	0.89
Odonata remains	1	0.17	1	0.89
Hemiptera	30	0.52	2	1.79
Lepidoptera	3	0.05	1	0.89
Diptera				
Chironomidae	300	5.23	36	32.14
Pupae	7	0.12	6	5.36
Remains	7	0.12	4	3.57
Insect remains	14	0.24	7	6.25
TOTAL INSECTA	363	6.33		
Pisces				
Anchoa mitchilli	5	0.09	4	3.59
Brevoortia patronus	3	0.05	3	2.68
Micropogonias undulatus	3	0.05	1	0.89
Dorosoma spp.	1	0.17	1	0.89
Arius felis	1	0.17	1	0.89
Unid. remains	22	0.38	18	16.07
TOTAL PISCES	35	0.61		
Other				
Vegetable material			5	4.46
Amorphous material			6	5.36
Sand			1	0.89
Amphipod Tubes			1	0.89
Fish Scales			1	0.89
TOTAL	5732	100.00		

*Non-additive.

Ictalurus punctatus - Channel Catfish
No. with food: 62

Food Taxa	No.	% Total	No. Fish Fed on Item*	% Total*
Nereidae remains	7	0.18	7	11.29
Oligochaeta remains	4	0.10	2	3.23
Mollusca				
Gastropoda				
Probythinella protera	1	0.03	1	1.61
Unidentified remains	1	0.03	1	1.61
Bivalvia				
Congeria leucophaeta	1	0.03	1	1.61
Rangia cuneata	4	0.10	2	3.23
Unidentified remains	2	0.05	2	3.23
TOTAL MOLLUSCA	9	0.24		
Crustacea				
Isopoda				
Cyathura polita	3	0.08	3	4.88
Edotea montosa	217	5.63	12	19.35
Asellus spp.	59	1.53	1	1.61
Unidentified remains	109	2.83	5	8.06
Amphipoda				
Corophium lacustre	126	3.27	19	30.65
Corophium louisianum	9	0.23	3	4.88
Corophium spp. remains	272	7.05	11	17.74
Gammarus "macromucronatus"	2	0.05	1	1.61
Gammarus mucronatus	600	15.56	3	4.88
Gammarus tigrinus	3	0.08	2	3.23
Gammarus spp. remains	35	0.90	6	9.68
Hyalella azteca	2	0.05	2	3.23
Grandidierella bonneroides	115	2.98	13	20.97
Unid. remains	68	1.76	17	27.42
Mysidacea				
Mysidopsis almyra	30	0.78	10	16.13
Taphromysis louisianae	6	0.16	4	6.45
Decapoda				
Callianassa jamaicense	12	0.31	3	4.88
Callinectes sapidus	9	0.23	6	9.68
Rhithropanopeus harrisii	13	0.34	3	4.88
Crab remains	2	0.05	2	3.23
TOTAL CRUSTACEA	1660	43.04		
Araneae	3	0.78	1	1.61
Insecta				
Ephemeroptera	2	0.05	2	3.23
Odonata	2	0.05	1	1.61

*Not additive.

Ictalurus punctatus - (Continued)

Food Taxa	No.	% Total	No. Fish Fed on Item*	% Total*
Hemiptera				
Corixidae	22	0.57	7	11.29
Belostoma spp.	4	0.10	2	3.23
Unid. remains	11	0.29	2	3.23
Hymenoptera				
Formicidae	1	0.03	1	1.61
Unidentified remains	1	0.03	1	1.61
Coleoptera				
Hydrophilidae	2	0.05	1	1.61
Dytiscidae	1	0.03	1	1.61
Unid. remains	3	0.08	2	3.23
Diptera				
Chironomidae larvae	1994	51.70	26	41.94
Ceratopogonidae larvae	13	0.34	6	9.68
Stratiomyiidae larvae	4	0.10	3	4.84
Pupal remains	46	1.19	6	9.68
Unid. remains	2	0.05	1	1.61
Insect remains	16	0.41	10	16.13
TOTAL INSECTA	2124	55.17		
Pisces				
Anchoa mitchilli	1	0.03	1	1.61
Brevoortia patronus	1	0.03	1	1.61
Myrophis punctatus	1	0.03	1	1.61
Symphurus plagiusa	1	0.03	1	1.61
Heterandria formosa	3	0.08	1	1.61
Fish remains	11	0.29	10	16.13
Other				
Vegetable material			19	30.65
Amorphous material			6	9.68
TOTAL	3859	100.00		

*Non-additive.

Menidia beryllina - Tidewater Silverside
No. with food: 325

Food Taxa	No.	% Total	No. Fish Fed on Item*	% Total*
Polychaeta				
Laeonereis culveri	15	0.24	14	4.31
Nereidae remains	10	0.16	9	2.77
Oligochaeta	33	0.52	5	1.54
Mollusca				
Bivalvia				
Macoma mitchilli	15	0.24	1	0.31
Unid. remains	14	0.22	6	1.85
Crustacea				
Unid. remains	16	0.25	9	2.77
Cladocera	72	1.13	17	5.23
Ostracoda	77	1.21	19	5.85
Copepoda				
Harpacticoida	31	0.49	6	1.85
Calanoida	2863	45.12	32	9.85
Unid. remains	7	0.11	1	0.31
Isopoda				
Cyathura polita	39	0.61	8	2.46
Unid. remains	1	0.02	1	0.31
Tanaidacea				
Hargaria rapax	72	1.13	30	9.23
Amphipoda				
Monoculodes edwardsi	NA	NA	3	0.92
Corophium lacustre	288	4.54	34	10.46
Corophium louisianum	554	8.73	60	18.46
Corophium spp. remains	27	0.43	9	2.77
Orchestia spp.	NA	NA	1	0.31
Gammarus "macromucronatus"	24	0.38	11	3.38
Gammarus mucronatus	62	0.98	18	5.54
Lepidactylus spp.	37	0.58	10	3.08
Gammarus tigrinus	42	0.66	21	6.46
Gammarus spp. remains	34	0.54	13	4.00
Grandidierella bonneroides	21	0.33	9	2.77
Melita spp.	9	0.14	6	1.85
Cerapus spp.	6	0.09	4	1.23
Unid. remains	55	0.87	16	4.92
Mysidacea				
Mysidopsis almyra	22	0.35	7	2.15
Taphromysis louisianae	1	0.02	1	0.31
Unid. remains	5	0.08	3	0.92
Decapoda				
Palaemonetes spp.	1	0.02	1	0.31
Callinectes sapidus	40	0.63	1	0.31
Crab remains	1	0.02	1	0.31
TOTAL CRUSTACEA	4407	69.45		

*Non additive.

Menidia beryllina - (Continued)

Food Taxa	No.	% Total	No. Fish Fed on Item*	% Total*
Araneae	9	0.14	7	2.15
Nematoda	1	0.01	1	0.31
Insecta				
Ephemeroptera	1	0.01	1	0.31
Hemiptera				
Corixidae	1	0.01	1	0.31
Trichoptera	1	0.01	1	0.31
Hymenoptera				
Formicidae	14	0.22	4	1.23
Unid. remains	1	0.01	1	0.31
Coleoptera	5	0.79	5	1.54
Diptera				
Chironomidae larvae	476	7.50	61	18.80
Ceratopogonidae larvae	4	0.06	3	0.92
Pupae	260	4.10	37	11.38
Unid. remains	57	0.90	27	8.31
Insect remains	13	0.20	12	3.69
TOTAL INSECTA	833	13.13		
Pisces				
Anchoa mitchilli	22	0.35	3	0.92
Brevoortia patronus	2	0.03	1	0.31
Menidia beryllina	9	0.14	7	2.15
Syngnathus scovelli	4	0.06	2	0.61
Unid. remains	198	3.12	25	7.69
TOTAL PISCES	235	3.70		
Other				
Vegetable material			33	10.15
Unrecog. material			39	12.00
Fish eggs			2	0.61
Sand			6	1.85
Planktonic rotifers			5	1.54
TOTAL	6346	100.00		

*Non-additive.

Gambusia affinis - Mosquitofish
No. with food: 14

Food Taxa	No.	% Total	No. Fish Fed on Item*	% Total*
Crustacea				
Unid. remains	1	2.50	1	7.14
Cladocera	1	2.50	1	7.14
Daphnia spp.	17	42.50	2	14.29
Ostracoda	1	2.50	1	7.14
Copepoda				
Calanoida	1	2.50	1	7.14
Cyclopoida	1	2.50	1	7.14
Unid. remains	11	27.50	4	28.57
Amphipoda	1	2.50	1	7.14
TOTAL CRUSTACEA	34	85.00		
Insecta				
Hemiptera				
Corixidae	1	2.50	1	7.14
Ranatra spp.	1	2.50	1	7.14
Unid. remains	4	10.00	4	28.57
TOTAL INSECTA	6	15.00		
Other				
Unrecog. material	—	—	1	7.14
TOTAL	40	100.00		

*Non-additive.

Lucania parva - Rainwater Killifish
No. with food: 37

Food Taxa	No.	% Total	No. Fish Fed on Item*	% Total*
Nereidae remains	4	2.14	4	10.81
Mollusca				
Bivalvia remains	41	21.93	8	21.62
Crustacea				
Unid. remains	2	1.07	2	5.41
Copepoda	1	0.53	1	2.70
Amphipoda				
Corophium lacustre	11	5.88	9	24.32
Gammarus "macromucronatus"	4	2.14	3	8.11
Gammarus mucronatus	2	1.07	2	5.41
Gammarus tigrinus	1	0.53	1	2.70
Grandidierella bonneroides	20	10.70	1	2.70
Unid. remains	13	6.95	9	24.32
TOTAL CRUSTACEA	54	28.88		
Insecta				
Diptera				
Chironomidae larvae	87	46.52	10	27.03
Other				
Unrecog. material			6	16.22
Fish eggs			1	2.70
Sand			1	2.70
Amphipod tubes			1	2.70
TOTAL	187	100.00		

*Non-additive.

Cyprinodon variegatus - Sheepshead Minnow
No. with food: 39

Food Taxa	No.	% Total	No. Fish Fed on Item*	% Total*
Mollusca				
Bivalvia remains	1	2.00	1	2.56
Crustacea				
Unid. remains	1	2.00	1	2.56
Copepoda				
Harpacticoida	10	20.00	1	2.56
Amphipoda				
Corophium lacustre	24	48.00	6	15.38
Unid. remains	7	14.00	2	5.13
TOTAL CRUSTACEA	42	84.00		
Insecta				
Diptera				
Chironomidae larvae	5	10.00	3	7.69
Unid. remains	2	4.00	2	5.13
TOTAL INSECTA	7			
Other				
Vegetable material			33	84.62
Unrecog. material			16	41.03
Bottom material	—	—	1	2.56
TOTAL	50	100.00		

*Non-additive.

Fundulus grandis - Gulf Killifish
No. with food: 84

Food Taxa	No.	% Total	No. Fish Fed on Item*	% Total*
Polychaeta				
Laeonereis culveri	5	1.00	5	5.95
Nereidae remains	8	1.60	8	9.52
Oligochaeta	8	1.60	2	2.38
Mollusca				
Gastropoda				
Neritina reclivata	1	0.20	1	1.19
Bivalvia				
Unid. remains	24	4.80	6	7.14
TOTAL MOLLUSCA	25	5.00		
Crustacea				
Unid. remains	4	0.80	4	4.76
Ostracoda	1	0.20	1	1.19
Isopoda				
Cyathura polita	1	0.20	1	1.19
Unid. remains	12	2.40	3	3.57
Tanaidacea				
Hargaria rapax	2	0.40	2	2.38
Amphipoda				
Corophium louisianum	5	1.00	3	3.57
Corophium spp. remains	2	0.40	2	2.38
Gammarus "macromucronatus"	28	5.60	5	5.95
Gammarus mucronatus	5	1.00	1	1.19
Gammarus tigrinus	24	4.80	9	10.71
Gammarus spp. remains	33	6.60	6	7.14
Grandidierella bonneroides	42	8.40	4	4.76
Melita spp.	4	0.80	1	1.19
Unid. remains	72	14.40	28	33.33
Mysidacea				
Unid. remains	3	0.60	1	1.19
Decapoda				
Shrimp remains	1	0.20	1	1.19
Callinectes sapidus	1	0.20	1	1.19
TOTAL CRUSTACEA	240	48.00		
Aranaea				
Insecta				
Ephemeroptera				
Ameletus spp.	9	1.80	1	1.19
Unid. remains	5	1.00	2	2.38
Odonata				
N. pentacantha	1	0.20	1	1.19
Unid. remains	1	0.20	1	1.19

*Non-additive.

Fundulus grandis - (Continued)

Food Taxa	No.	% Total	No. Fish Fed on Item*	% Total*
Hemiptera				
Corixidae	20	4.00	5	5.95
Unid. remains	15	3.00	5	5.95
Hymenoptera				
Formicidae	2	0.40	2	2.38
Coleoptera	1	0.20	1	1.19
Orthoptera	1	0.20	1	1.19
Diptera				
Chironomidae larvae	20	4.00	10	11.91
Pupae	4	0.80	4	4.76
Unid. remains	75	15.00	5	5.95
Insect remains	52	10.40	6	7.14
TOTAL INSECTA	206	41.20		
Pisces				
Menidia beryllina	1	0.20	1	1.19
Gobiosoma bosci	1	0.20	1	1.19
Unid. remains	5	1.00	5	5.95
TOTAL PISCES	7	1.40		
Other				
Vegetable material			17	20.24
Unrecog. material			5	5.95
Fish eggs			3	3.57
Sand			2	2.38
Bottom material			4	4.76
TOTAL	500	100.00		

*Non-additive.

Micropterus salmoides - Largemouth Bass
No. with food: 35

Food Taxa	No.	% Total	No. Fish Fed on Item*	% Total*
Mollusca				
Bivalvia remains	3	0.43	3	8.57
Crustacea				
Cladocera	29	4.15	2	5.71
Isopoda				
Cyathura polita	3	0.43	2	5.71
Amphipoda				
Corophium lacustre	31	4.43	6	17.14
Corophium spp. remains	20	2.86	2	5.71
Gammarus "macromucronatus"	43	6.15	7	20.00
Gammarus mucronatus	13	1.86	6	17.14
Gammarus tigrinus	2	0.29	1	2.86
Gammarus spp. remains	4	0.57	2	5.71
Unid. remains	4	0.57	2	5.71
Mysidacea				
Mysidopsis almyra	22	3.15	3	8.57
Taphromysis louisianae	43	6.15	5	14.29
Unid. remains	21	3.00	4	11.43
Decapoda				
Palaemonetes spp.	11	1.57	7	20.00
Rhithropanopeus harrisii	11	1.57	4	11.43
Crab remains	1	0.14	1	2.86
Decapod remains	6	0.86	1	2.86
TOTAL CRUSTACEA	264	37.77		
Araneae	1	0.14	1	2.86
Insecta				
Ephemeroptera	4	0.57	2	5.71
Hemiptera				
Corixidae	6	0.86	3	8.57
Trichoptera	2	0.29	1	2.86
Orthoptera	1	0.14	1	2.86
Diptera				
Chironomidae larvae	389	55.65	4	11.43
Ceratopogonidae larvae	8	1.44	2	5.71
Pupae	5	0.72	2	5.71
Insect remains	1	0.14	1	2.86
TOTAL INSECTA	416	59.51		
Pisces				
Menidia beryllina	1	0.14	1	2.86
Gobiosoma bosci	1	0.14	1	2.86
Syngnathus scovelli	1	0.14	1	2.86
Lepomis macrochirus	2	0.29	1	2.86
Unid. remains	10	1.43	9	25.71
TOTAL PISCES	15	2.15		

*Non additive.

Micropterus salmoides - (Continued)

Food Taxa	No.	% Total	No. Fish Fed on Item*	% Total*
Other				
Vegetable material			3	8.57
Amorphous material			5	14.29
TOTAL	699	100.00		

*Non-additive.

Lepomis punctatus - Spotted Sunfish
No. with food: 19

Food Taxa	No.	% Total	No. Fish Fed on Item*	% Total*
Mollusca				
Gastropoda remains	4	2.37	2	10.53
Congeria leucophaeta	1	0.59	1	5.26
Bivalvia remains	2	1.18	1	5.26
TOTAL MOLLUSCA	7	4.14		
Crustacea				
Isopoda	3	1.76	2	10.53
Tanaidacea				
Hargaria rapax	3	1.76	2	10.53
Amphipoda				
Corophium lacustre	15	8.88	7	36.84
Corophium louisianum	2	1.18	1	5.26
Gammarus "macromucronatus"	39	23.08	6	31.58
Gammarus mucronatus	2	1.18	1	5.26
Gammarus remains	60	35.50	9	47.37
Unid. remains	9	5.33	3	15.79
Decapoda				
Palaemonetes spp.	3	1.76	1	5.26
______________	3	1.76	1	5.26
Crab remains	9	5.33	5	26.32
TOTAL CRUSTACEA	148	87.57		
Insecta				
Ephemeroptera	1	0.59	1	5.26
Odonata				
Zygoptera	3	1.76	2	10.53
Hymenoptera	1	0.59	1	5.26
Diptera				
Chironomidae larvae	8	4.73	6	31.58
Unid. remains	1	0.59	1	5.26
TOTAL INSECTA	14	8.28		
Other				
Vegetable material			7	36.84
Unrecognizable material	___	___	9	47.37
TOTAL	169	100.00		

*Non-additive.

Lepomis macrochirus - Bluegill Sunfish
No. with food: 15

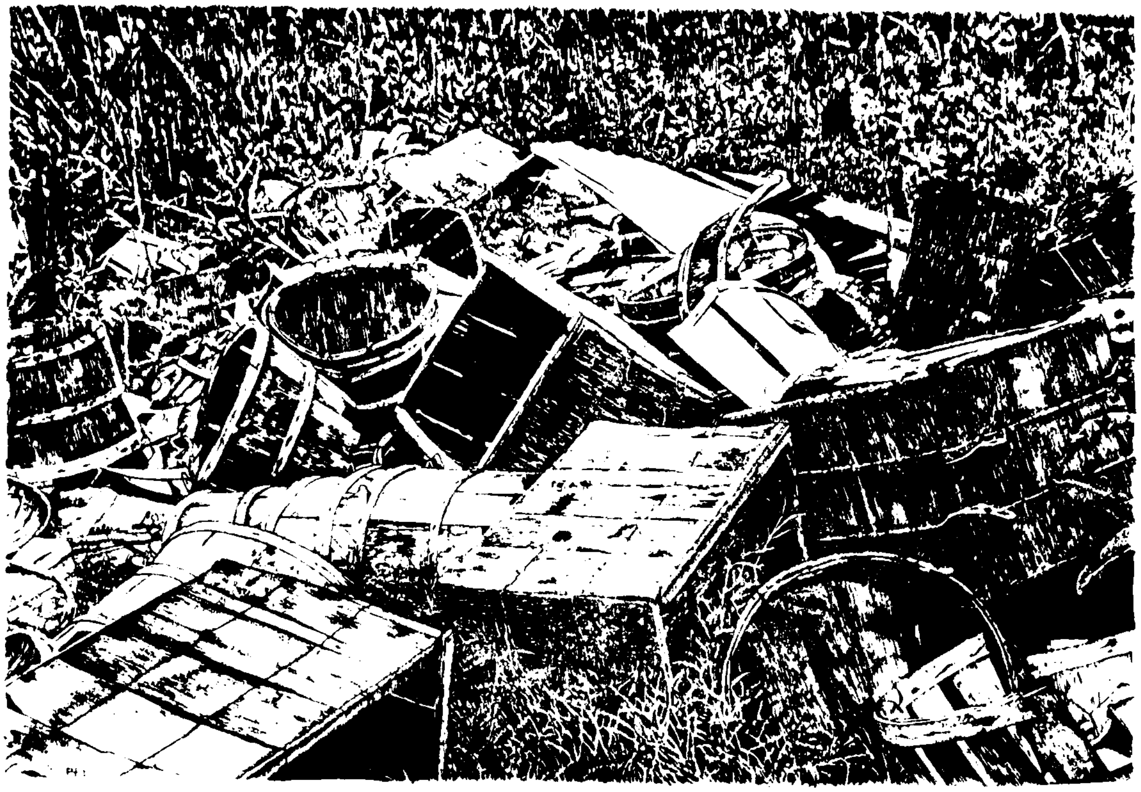
Food Taxa	No.	% Total	No. Fish Fed on Item*	% Total*
Mollusca				
Gastropoda remains	3	0.65	2	13.33
Bivalve remains	9	1.95	3	20.00
TOTAL MOLLUSCA	12	2.60		
Crustacea				
Cladocera	1	0.22	1	6.67
Copepoda				
Calanoida	1	0.22	1	6.67
Cyclopoida	4	0.87	1	6.67
Unid. remains	257	55.75	5	33.33
Isopoda	38	8.24	6	40.00
Amphipoda				
Corophium spp. remains	1	0.22	1	6.67
Gammarus spp. remains	8	1.74	4	26.67
Unid. remains	4	0.87	3	20.00
TOTAL CRUSTACEA	314	68.11		
Insecta				
Ephemeroptera	2	0.43	1	6.67
Hemiptera				
Corixidae	8	1.74	4	25.57
Diptera				
Chironomidae larvae	113	24.51	10	66.67
Pupae	8	1.74	3	20.00
Insect remains	2	0.43	2	13.33
TOTAL INSECTA	133	28.85		
Pisces				
Gobiosoma bosci	1	0.22	1	6.67
Other				
Vegetable material			1	6.67
Unrecognizable material	—	—	1	6.67
TOTAL	461	100.00		

*Non-additive.

Lepomis microlophus - Redear Sunfish
No. with food: 7

Food Taxa	No.	% Total	No. Fish Fed on Item*	% Total*
Nereidae remains	2	1.94	2	28.57
Oligochaeta remains	1	0.97	1	14.29
Mollusca				
Bivalvia				
Congeria leucophaeta	5	4.85	1	14.29
Rangia cuneata	1	0.97	1	14.29
Unid. remains	50	48.54	1	14.29
TOTAL MOLLUSCA	56	54.36		
Crustacea				
Isopoda				
Cyathura polita	1	0.97	1	14.29
Unid. remains	2	1.94	1	14.29
Amphipoda				
Corophium spp. remains	20	19.42	1	14.29
Gammarus spp. remains	1	0.97	1	14.29
Unid. remains	11	10.68	3	42.86
TOTAL CRUSTACEA	35	33.98		
Insecta				
Diptera				
Chironomidae larvae	9	8.74	3	42.86
TOTAL INSECTA	9	8.74		
TOTAL	103	100.00		

*Non-additive.



Refuse pile on north shore of Lake Pontchartrain

Chapter 15

MACROPLANKTON MOVEMENT THROUGH THE TIDAL PASSES OF LAKE PONTCHARTRAIN

by

Marion T. Fannaly

ABSTRACT

Monthly plankton collections were made at The Rigolets, Chef Menteur Pass, and the Inner Harbor Navigation Canal (IHNC). The greatest number of macroplankters occurred in the samples at night, during flood tides, and at mid-depth in the passes. No significant differences were found among the three stations. Peak catches occurred in spring and fall. Distinct seasonal differences in the species composition of the samples were noted. Migration through the passes is considered essential to the maintenance of populations of most of the dominant species of Lake Pontchartrain.

INTRODUCTION

Lake Pontchartrain is a large, oligohaline estuary connected indirectly to the Gulf of Mexico by three passes. Two of these, The Rigolets and Chef Menteur Pass, connect Lake Pontchartrain with Lake Borgne, which in turn extends via the Mississippi Sound into the Gulf of Mexico. The third pass, the Inner Harbor Navigation Canal (IHNC), is artificial and much smaller than the two natural passes. It is connected to Lake Borgne through the Intracoastal Waterway and directly to the Gulf by the Mississippi River Gulf Outlet (MRGO). The high salinity

water from the MRGO makes the IHNC the most saline of the passes, and it has been credited with increasing the overall salinity of the lake (Tarver and Dugas 1973). It also provides the most direct route into the lake from the Gulf.

Early in the study of the nekton of Lake Pontchartrain, the investigators realized that it would be difficult to adequately describe the ecology of the lake without having some idea of the relationship of the passes to it. Preliminary sampling, review of the available literature, and conversations with previous investigators revealed that most of the marine component of the nekton community inhabited the lake only during the warmer part of the year. This implied that there must be a large movement of these animals through the passes, which comprise the only entrances and exits. It was decided that the normal nekton sampling program would adequately show the arrival and departure of the juvenile and adult fishes, but this study was conducted because more information was needed on the migration of larval to post-larval stages into the lake.

There have been few published studies on the movements of fish through tidal passes in Louisiana. Most of the work on the Gulf Coast has been done in Texas. Pearson (1929) discussed the importance of the tidal passes along the south Texas coast to the sciaenids of the area. Hoese (1965) studied the movement of larval fishes through Aransas Pass. King (1971) reported on the migration patterns of fish and shellfish through Cedar Bayou, Texas. Fore and Baxter (1972) studied immigration of larval menhaden at Galveston Entrance, Texas. Sabins (1973, Sabins and Truesdale 1974) studied diel and seasonal occurrence of larval and

juvenile fishes in Caminada Pass at Grand Isle, Louisiana. Other investigators have estimated movement of immature fishes from catches made inside the bays.

One of the primary goals of this study was to obtain direct information on the movement of the organisms into and out of the lake. Stationary nets that would capture organisms traveling with the tidal flow were used. The same approach has been used successfully by Massman (1952), Dovel (1964), Graham and Venno (1968), and King (1971) with plankton nets. Commercial fishermen using large "butterfly" or "wing" nets also take advantage of the tidal movement to catch penaeid shrimp.

MATERIALS AND METHODS

The sampling was conducted from a chartered boat equipped with a side-mounted electric winch. The boat was anchored as near to the deepest part of the channel as possible. The location selected in The Rigolets was about 200 m southeast of the U.S. Highway 90 bridge and 200 m northeast of Fort Pike. The water depth is about 11 m at this site. At Chef Menteur Pass the boat was anchored northwest of the Highway 90 bridge, about 100 m off the northeast shore of the pass during April, May, and June. The sampling site was then shifted to the southeast side of the bridge about 100 m northeast of Fort Macomb for the remainder of the study. Water depth was 10 m at the first site and 15 m at the second. Several sites in the IHNC were used because of the heavy commercial traffic in the area. All were in the vicinity of the Interstate 10 bridge. Starting in June, the boat was anchored on the south side of the Almanaster Street drawbridge behind the west fender in about 6 m of water.

The sampling period extended from February 1978 to March 1979. The first set of samples was taken in the last week of February during flood tide at The Rigolets. No samples were collected at Chef Menteur Pass or the IHNC during this month. From April 1978 through March 1979, samples were taken monthly during the first full week of the respective month at each of the three passes for a 24-hour period. The only major departure from this schedule occurred when mechanical problems with the boat prevented sampling at the IHNC during November.

The sampling gear for the study consisted of a 0.5 m diameter plankton net with 1.34 mm mesh. The net was mounted one meter above the end of the cable where a large weight was attached. A General Oceanics Model 2030 flow meter was mounted inside the mouth of the net to measure the amount of water filtered. A similar net of 0.363 mm mesh was attached immediately above the lower net for zooplankton collection. A Van Dorn-type water sampling bottle mounted above the top net was used to collect water samples for measurement of salinity and temperature. Fifteen-minute collections were made one meter above the bottom, at approximately the middle of the water column, and one meter below the surface at three-hour intervals for a period of 24 hours at each station. On several occasions, clogging of the net by ctenophores forced reduction of sampling time. A period of about 96 hours was normally required to sample the three passes. The same order was always observed in the sampling: The Rigolets was done first; Chef Menteur Pass, second; and the IHNC, last. Samples were preserved in 10% formalin and transported to the laboratory in Baton Rouge for analysis.

At the laboratory the samples were fixed in the formalin for at least one week, then rinsed with water, and placed in 45% isopropanol

for permanent storage. Because of the limited time available, only the fish and decapod crustaceans were identified and counted. The fish, penaeid shrimp, and blue crabs were measured to the nearest tenth of a mm with either an eyepiece micrometer in a Bausch and Lomb steremicroscope or a vernier caliper, according to the size of the specimen. Standard length was used for fish, carapace width for crabs, and length from the rostrum to the end of the telson for shrimp. A maximum of eight specimens of a species were measured for each sample. All of the data were coded and punched on computer cards for analysis.

The experiment was designed as a split-split plot arrangement of treatments in a randomized blocks design. Each of the three passes constituted a main plot and was split into three depths. Each depth contained a 2 x 2 factorial arrangement of tide and light. The effects of seasonal variation were reduced by blocking on months. The catch data were analyzed using a square root transformation of the raw catch data adjusted to a standard sampling time of 15 minutes. The catch data for the 10 most abundant species were similarly analyzed. Data from February 1978 and November 1978 were not included in the overall analysis because all stations were not sampled in those months.

RESULTS

I. Physical Parameters

Salinities and temperatures measured at the three stations are listed in Tables 1 and 2, respectively. The lowest salinity of the year (0.1°/₀₀) was measured at The Rigolets and the highest (14.5°/₀₀), at the IHNC. The average salinities for the year also show the same pattern. The Rigolets is the freshest of the passes because of the freshwater

Table 1. Mean Salinities ($^{o}/_{oo}$) and Range Measured at Each Station by Month in Tidal Passes of Lake Pontchartrain, LA, 1978-1979

	The Rigolets	Chef Menteur Pass	IHNC
February 1978	----	----	----
April	2.3 (1.8-3.2)	4.3 (4.0-4.7)	7.2 (4.3-11.1)
May	4.0 (3.2-4.9)	5.1 (4.4-5.6)	3.9 (3.4-4.0)
June	2.0 (1.0-3.0)	3.9 (3.6-4.1)	6.2 (4.0-9.4)
July	3.0 (2.7-3.2)	4.7 (2.1-13.0)	10.5 (6.2-14.5)
August	6.9 (6.0-9.2)	4.7 (4.0-5.3)	5.2 (4.0-8.3)
September	4.1 (3.9-4.3)	5.8 (5.2-6.5)	10.3 (6.5-13.0)
October	4.3 (3.5-5.0)	4.2 (3.6-5.0)	5.5 (3.8-11.2)
November	7.8 (4.0-11.0)	5.2 (4.0-8.0)	----
December	4.8 (3.8-6.5)	5.6 (4.7-6.9)	4.7 (3.8-6.1)
January 1979	4.2 (3.3-6.3)	4.6 (4.1-5.1)	6.4 (6.0-7.0)
February	1.0 (0.1-2.2)	2.1 (1.5-3.2)	2.8 (2.4-3.2)
March	1.5 (1.0-1.8)	1.9 (1.8-2.0)	1.8 (0.6-4.1)
Overall	3.8 (0.1-11.0)	4.3 (1.5-13.0)	6.0 (0.6-14.5)

Table 2. Mean Water Temperatures (°C) and Range Measured at Each Station by Month in Tidal Passes of Lake Pontchartrain, LA, 1978-1979

	The Rigolets	Chef Menteur Pass	IHNC
February 1978	13.0 (11.5-14.0)	----	----
April	19.8 (19.0-22.0)	22.0 (21.0-24.0)	19.8 (19.5-20.8)
May	23.1 (22.5-25.0)	24.0 (23.4-24.7)	22.1 (21.7-23.0)
June	27.2 (25.5-29.0)	29.2 (26.7-32.6)	28.0 (27.0-29.0)
July	29.6 (28.0-31.0)	29.2 (27.0-31.7)	29.4 (29.0-31.0)
August	28.1 (27.0-29.0)	25.9 (25.0-26.7)	27.7 (26.0-30.0)
September	27.8 (27.0-30.0)	28.4 (28.0-30.0)	28.7 (28.0-30.0)
October	25.2 (24.0-27.5)	25.9 (24.5-29.0)	26.3 (25.0-28.0)
November	21.5 (19.5-26.0)	15.7 (14.0-18.0)	----
December	15.6 (14.3-17.0)	17.0 (16.4-18.0)	19.5 (18.7-20.5)
January 1979	8.1 (5.0-9.0)	6.6 (5.8-7.8)	9.2 (8.4-9.9)
February	8.3 (7.0-10.0)	7.2 (6.3-8.2)	7.7 (6.8-9.5)
March	14.2 (13.0-16.0)	13.9 (13.0-16.0)	15.6 (14.0-18.0)
Overall	20.8 (5.0-31.0)	20.6 (5.8-32.6)	21.9 (6.8-31.0)

discharge from the Pearl River, which probably has its greatest effect during the winter and early spring rains. In the summer and fall, the salinity at The Rigolets is very similar to that of Chef Menteur Pass, which also connects with Lake Borgne. The IHNC is normally more saline than the other passes because of its direct connection to the Gulf of Mexico through the MRGO. Significant differences in salinities ($P < .01$) were found among the three passes when tested in a randomized blocks design with months as blocks; highest salinities were found in the IHNC, followed by Chef Menteur Pass and The Rigolets.

Temperatures were less variable than salinities among the passes. The lowest average temperature occurred at The Rigolets and the highest at the IHNC. The lowest water temperature (5.0°C) was measured at The Rigolets in January 1979 and the highest (32.6°C), at Chef Menteur Pass in June 1978. Differences in temperature among the passes were statistically significant ($P < .01$); the highest water temperature was at the IHNC.

II. Factors that Influence Macroplankton Movement

The catch data for the overall study and for each month are presented in Tables 3 and 4, respectively, sorted by the various factors considered in the analysis. The Analysis of Variance (ANOV) table for the statistical analysis is presented in Table 5. The first and most obvious effect on the catches would be that caused by months, but monthly changes were not found to be significant. Although there are changes in the species composition of the macroplankton with changes in season, the total numbers of animals collected are more constant. That is, when one species declines in abundance, another becomes more common, as there is some overlapping of the spawning seasons of the species involved, and substantial movement through the passes occurs at all times of the year.

Table 3. Numbers of Organisms Collected February 1978 through March 1979, Sorted by Station, Tidal Flow, Time of Day, and Water Depth in Tidal Passes of Lake Pontchartrain, LA

					STATION			TIDE		TIME		DEPTH		
	Species	Total	Mean Length	Standard Deviation	Rigolets	Chef Menteur	IHNC	Ebb	Flood	Day	Night	Bottom	Middle	Top
1	Anchoa mitchilli	6900	25.4	13.3	1605	2528	2767	1786	5096	1015	5885	2880	3382	1238
2	Brevoortia patronus	893	25.0	19.2	538	108	247	123	768	89	804	303	302	288
3	Callinectes sapidus	864	11.7	13.8	228	280	356	124	727	166	698	276	401	187
4	Micropogonias undulatus	524	17.3	11.4	156	110	258	106	417	71	453	283	189	52
5	Gobiosoma bosci	336	10.6	5.3	83	171	82	93	237	54	282	110	153	73
6	Palaemonetes pugio	237			16	85	136	138	95	30	207	97	68	72
7	Microgobius gulosus	181	9.6	1.4	24	138	19	18	160	54	127	64	77	40
8	Penaeus aztecus	168	19.6	9.7	33	32	103	100	67	19	149	39	54	75
9	Gobiesox strumosus	96	12.0	7.5	65	30	1	7	88	41	55	43	15	38
10	Callianassa jamaicense	96			84	11	1	21	75	5	91	30	51	15
11	Menidia beryllina	76	13.3	9.7	28	27	21	39	36	11	65	24	26	26
12	Cynoscion arenarius	43	20.6	19.6	22	10	11	18	25	17	26	16	22	5
13	Trinectes maculatus	25	11.5	18.3	12	10	3	1	23	13	12	8	10	7
14	Syngnathus scovelli	24	44.6	23.9	9	10	5	8	16	14	10	3	7	14
15	Myrophis punctatus	19	153.7	80.3	10	5	4	10	9	5	14	6	10	3
16	Penaeus setiferus	15	19.0	16.9	1	7	7	5	10		15	4	9	2
17	Rhithropanopeus harrisii	12	9.3	6.5	3	8	1	10	2	5	7	7	4	1
18	Syngnathus louisianae	11	44.2	13.3	7	4		3	8	7	4	4	4	3
19	Symphurus plagiusa	11	50.9	23.3	4	6	1	6	4	2	9	6	5	
20	Microgobius thalassinus	11	27.5	3.7	7	4		7	4	3	8	5	6	
21	Membras martinica	10	66.6	10.1	1	9		1	9		10	1	1	8
22	Mugil cephalus	9	37.8	41.7	1	8		4	5		9	1	1	8
23	Paralichthys albigutta	8	9.9	0.7			8		8		8	2	6	
24	Acetes americanus	8	16.1	1.1			8	3	5	1	7	3	3	2
25	Palaemonetes paludosus	7			3	4		5	2		7	1		6
26	Elops saurus	7	25.5	15.3	4		3	3	4		7	1	2	4
27	Palaemonetes vulgaris	7			1	4	2	3	4		7	3	4	
28	Prionotus tribulus	6	39.4	6.2	4	1	1	4	2	4	2	2	4	
29	Sphoeroides parvus	6	13.5	15.4	4	2		1	5	3	3	3	2	1
30	Anguilla rostrata	6	55.5	7.2	1	3	2		6	1	5	3	1	2
31	Leiostomus xanthurus	6	18.6	15.7	3	2	1	1	5		6	1	1	4
32	Palaemonetes intermedius	5			2	2	1	2	3		5	2	3	
33	Paralichthys lethostigma	5	9.4	1.0			5		5		5	5		
34	Cynoscion nebulosus	3	60.6	87.8		2	1		3	1	2		2	1
35	Lagodon rhomboides	2	14.8	3.2	2				2		2		1	1
36	Gobionellus hastatus	1	16.2				1	1			1	1		
37	Gobionellus shufeldti	1	26.0				1	1			1		1	
38	Oligoplites saurus	1	17.9		1				1	1			1	
39	Bairdiella chrysura	1	12.3		1				1	1			1	
40	Heterandria formosa	1	20.0				1	1			1	1		
41	Palaemonetes kadiakensis	1			1				1		1	1		
42	Poecilia latipinna	1	36.3		1			1			1			1
43	Citharichthys spilopterus	1	22.8				1	1			1		1	
44	Arius felis	1	79.1				1		1		1	1		
45	Strongylura marina	1	12.2			1			1	1				1
46	Macrobrachium ohione	1			1				1		1			1
47	Achirus lineatus	1	33.0			1			1		1			1
48	Lucania parva	1	22.9			1		1			1			1
49	Chasmodes bosquianus	1	8.6			1		1			1		1	
	Totals	10651			2966	3625	4060	2657	7942	1634	9017	3640	4831	2180

Table 4. Numbers of Organisms Collected Monthly, Sorted by Station, Tidal Flow, Time of Day, and Water Depth in Tidal Passes of Lake Pontchartrain, LA

Species	Total	Mean Length	Standard Deviation	STATION: Rigolets	STATION: Chef Menteur	STATION: IHNC	TIDE: Ebb	TIDE: Flood	TIME: Day	TIME: Night	DEPTH: Bottom	DEPTH: Middle	DEPTH: Top
FEBRUARY 1978													
Brevoortia patronus	367	24.2	3.4	367				367	41	326	121	123	123
Anchoa mitchilli	110	39.5	12.9	110				110	10	100	49	45	16
Micropogonias undulatus	58	24.1	9.9	58				58	20	38	24	14	20
Callinectes sapidus	10	8.7	6.9	10				10	1	9	5	3	2
Lagodon rhomboides	2	14.8	3.2	2				2		2		1	1
Leiostomus xanthurus	1	[illegible]		1				1		1			1
Myrophis punctatus	1	[illegible]		1				1		1	1		
	549			549				549	72	477	200	186	163
APRIL 1978													
Callinectes sapidus	71	10.6	9.9	41	28	2	1	68	7	64	15	41	15
Penaeus aztecus	71	12.7	3.9	3	2	66	63	7	1	70	13	23	35
Brevoortia patronus	61	17.8	5.8	55	4	2	5	56	3	58	12	42	7
Micropogonias undulatus	21	19.6	9.1	8	11	2	12	9	10	11	14	6	1
Anchoa mitchilli	16	31.6	19.7	16			1	15	1	15	3	12	1
Cynoscion arenarius	16	13.7	18.9	15		1	7	9	6	10	5	10	1
Callianassa jamaicense	15			15				15		15	3	6	6
Elops saurus	7	25.5	15.3	4		3	3	4		7	1	2	4
Myrophis punctatus	2	45.0	1.4	2				2		2		2	
Gobionellus hastatus	1	16.2				1	1			1	1		
Macrobrachium ohione	1			1				1		1			1
	282			160	45	77	93	186	28	254	67	144	71
MAY 1978													
Anchoa mitchilli	1322	18.7	12.4	469	799	54	74	1245	470	852	352	518	452
Callinectes sapidus	99	11.2	5.6	22	38	39	39	60	18	81	24	39	36
Penaeus aztecus	96	20.9	9.3	29	30	37	37	59	18	78	25	31	40
Gobiesox strumosus	93	10.4	1.2	64	29		6	86	41	52	40	15	38
Menidia beryllina	63	10.3	1.8	26	16	21	36	26	6	57	21	19	23
Brevoortia patronus	28	26.9	5.4		2	26	26	2	1	27	1	18	9
Callianassa jamaicense	23			19	3	1	1	22	2	21	11	9	3
Cynoscion arenarius	21	17.9	10.3	6	7	8	10	11	8	13	6	11	4
Gobiosoma bosci	19	9.4	5.7		12	7	7	12	7	12	1	9	9
Syngnathus scovelli	10	29.6	9.1	4	4	2	3	7	8	2	2	2	6
Syngnathus louisianae	10	42.2	12.1	7	3		2	8	7	3	3	4	3
Micropogonias undulatus	9	45.8	10.6		7	2	2	7	1	8	6	3	
Sphoeroides parvus	4	7.5	0.4	4				4	1	3	3		1
Myrophis punctatus	3	165.0	82.6		2	1	1	2	1	2		2	1
Trinectes maculatus	2	71.7	7.5		1	1	1	1	1	1	1		1
Palaemonetes pugio	1				1			1		1			1
Symphurus plagiusa	1	35.7				1	1			1		1	
Penaeus setiferus	1	24.0				1	1			1		1	
Leiostomus xanthurus	1	49.2			1			1		1			1
Gobionellus shufeldti	1	26.0				1	1			1		1	
Heterandria formosa	1	20.0				1	1			1	1		
Citharichthys spilopterus	1	22.8				1	1			1	1		
Strongylura marina	1	12.2			1			1	1				1
	1810			650	956	204	250	1555	591	1219	[illegible]	[illegible]	629

Table 4. (Continued)

Species	Total	Mean Length	Standard Deviation	STATION			TIDE		TIME		DEPTH		
				Rigolets	Chef Menteur	IHNC	Ebb	Flood	Day	Night	Bottom	Middle	Top
JUNE 1978													
Anchoa mitchilli	1159	21.6	11.2	493	605	61	1136	23	87	1072	377	435	347
Callinectes sapidus	76	13.8	12.0	64	3	9	21	55	60	16	31	19	26
Gobiosoma bosci	53	8.2	2.5	43	10		47	6	11	42	20	21	12
Callianassa jamaicense	19			18	1		19		3	16	7	7	5
Palaemonetes pugio	4			1	1	2	4		1	3	2	1	1
Microgobius gulosus	3	10.1	0.3	1	1	1	3			3	1		2
Myrophis punctatus	2	76.7	2.1	1		1	2			2	1		1
Rhithropanopeus harrisii	2				1	1	1	1	1	1	1	1	
Acetes americanus	2					2	2			2		2	
Cynoscion arenarius	1	31.1		1			1		1		1		
Trinectes maculatus	1	4.9		1				1	1				1
Brevoortia patronus	1	48.0				1	1			1		1	
Micropogonias undulatus	1	56.0		1			1		1		1		
Syngnathus louisianae	1	64.4			1		1			1	1		
Menidia beryllina	1	31.8		1			1			1			1
Palaemonetes intermedius	1					1	1			1	1		
	1327			625	623	79	1241	86	166	1161	444	487	396
JULY 1978													
Anchoa mitchilli	316	18.7	8.0	169	146	1	92	224	17	299	87	133	96
Gobiosoma bosci	31	9.9	3.5	22	7	2	12	19	5	26	8	20	3
Microgobius gulosus	22	9.7	1.0	14	7	1	10	12	4	18	7	12	3
Callinectes sapidus	18	22.6	26.1	7	7	4	6	12	7	11	5	8	5
Palaemonetes pugio	16					16	15			16	3	9	4
Trinectes maculatus	8	5.2	1.5	8				8	7	1	3	3	2
Penaeus setiferus	3	7.5				3	3			3		3	
Palaemonetes vulgaris	2			1	1		2			2	1	1	
Brevoortia patronus	1	38.0					1		1				1
Syngnathus scovelli	1	39.7		1				1	1				1
Bairdiella chrysura	1	12.3		1				1	1			1	
Chasmodes bosquianus	1	8.6			1		1			1		1	
	420			223	170	27	142	277	43	377	114	191	115
AUGUST 1978													
Anchoa mitchilli	270	18.4	11.9	28	240	2	2	265	220	50	107	83	80
Callinectes sapidus	57	20.5	32.7	12	35	10	9	46	37	20	31	17	9
Microgobius gulosus	53	9.6	2.0	3	50			52	45	8	15	24	14
Gobiosoma bosci	51	10.7	3.3	2	47	2	2	44	23	28	21	16	14
Palaemonetes pugio	33			2		31	31	2	19	14	28	2	3
Menidia beryllina	7	21.1	17.3		7			7	4	3	3	3	1
Trinectes maculatus	4	6.2	0.4		4			4	3	1	2	1	1
Penaeus setiferus	3	46.0	18.5		3			3		3	1	1	1
Symphurus plagiusa	3	23.9			3			2	2	1	3		
Myrophis punctatus	2	94.0	4.2		2			2	2			2	
Cynoscion arenarius	2	65.8	31.4		2			2	2		2		
Syngnathus scovelli	2	57.7	17.7		2			2	2			2	
Cynoscion nebulosus	2	1.0	1.8		2			2	1	1		1	1
Prionotus tribulus	1	38.0			1			1	1			1	
Sphoeroides parvus	1	44.9			1			1	1			1	
Callianassa jamaicense	1				1			1		1			1
[illegible]	1	17.9		1				1	1			1	
	493			48	400	45	44	437	363	130	213	155	125

Table 4. (Continued)

Species	Total	Mean Length	Standard Deviation	STATION: Rigolets	STATION: Chef Menteur	STATION: IHNC	TIDE: Ebb	TIDE: Flood	TIME: Day	TIME: Night	DEPTH: Bottom	DEPTH: Middle	DEPTH: Top
September 1978													
Anchoa mitchilli	256	20.8	10.3	13	227	16		251	1	255	74	139	43
Gobiosoma bosci	80	8.5	2.7	1	79			79	1	79	25	31	24
Palaemonetes pugio	66			1	11	54	47	18		66	33	24	9
Callinectes sapidus	49	7.6	3.1	22	25	2	2	43	3	46	7	30	12
Microgobius gulosus	29	8.9	1.5	2	27		1	28	3	26	10	11	8
Callianassa jamaicense	28			22	6			28		28	6	22	
Trinectes maculatus	8	6.5	0.6	3	4	1		7	1	7	2	4	2
Menidia beryllina	2	12.9	3.9	1	1			2		2		2	
Syngnathus scovelli	2	19.8	1.1		2		1	1	1	1			2
Cynoscion nebulosus	2	9.9	1.8		2			2	1	1		1	1
Penaeus setiferus	1	8.1			1			1		1	1		
Membras martinica	1	76.0			1			1		1	1		
	523			65	384	74	51	460	11	512	159	263	101
OCTOBER 1978													
Anchoa mitchilli	1882	20.0	9.3	6	198	1678	13	1866	29	1853	486	1309	87
Callinectes sapidus	279	6.7	4.3	4	56	219	1	275	13	266	62	189	28
Palaemonetes pugio	74			5	44	25	8	64		74	24	18	32
Microgobius gulosus	74	9.5	0.9	4	53	17	4	68	2	72	31	30	13
Gobiosoma bosci	73	8.1	1.6	1	3	69	1	72		73	27	43	3
Membras martinica	8	64.6	10.5		8			8		8			6
Penaeus setiferus	4	11.8	3.7		2	2		4		4	1	2	1
Acetes americanus	3	15.7	1.0			3		3		3	3		
Trinectes maculatus	2	10.2	5.4		1	1		2		2		2	
Cynoscion arenarius	2	22.3	4.7		1	1		2		2	1	1	
Cynoscion nebulosus	2	9.9	1.8		2			2	1	1		1	1
	2402			20	367	2015	27	2365	44	2358	635	1594	173
NOVEMBER 1978													
Callinectes sapidus	23	7.7	5.9	17	6		5	18		23	8	8	7
Anchoa mitchilli	13	26.9	5.7	7	6		9	4	10	3	6	7	
Callianassa jamaicense	10			10			1	9		10	3	7	
Micropogonias undulatus	9	10.5	1.9	5	4		5	4	2	7	4	4	1
Gobiosoma bosci	5	18.4	10.9		5		4	1		5	3	2	
Penaeus setiferus	2	11.3	1.8	1	1		1	1		2	1	1	
Palaemonetes pugio	1			1			1			1	1		
Symphurus plagiusa	1	20.4		1			1			1		1	
Membras martinica	1	71.8		1			1			1		1	
Sphoeroides parvus	1	6.4			1		1		1			1	
Poecilia latipinna	1	36.3		1			1			1			1
Achirus lineatus	1	33.0			1			1		1			1
	68			44	24		30	38	13	55	26	32	10

Table 4. Continued

Species	Total	Mean Length	Standard Deviation	STATION			TIDE		TIME		DEPTH		
				Rigolets	Chef Menteur	IHNC	Ebb	Flood	Day	Night	Bottom	Middle	Top
DECEMBER 1978													
Anchoa mitchilli	143	37.4	8.5	128	15		128	15	8	135	27	90	26
Callinectes sapidus	97	9.8	8.3	11	52	34	9	88	1	96	55	17	25
Micropogonias undulatus	53	11.5	3.2	27	14	12	27	26	5	48	33	14	6
Gobiosoma bosci	16	18.1	3.6	12	3	1	15	1	4	12	2	8	6
Rhithropanopeus harrisii	8			2	6		7	1	3	5	4	3	1
Microgobius thalassinus	8	27.5	4.3	6	2		5	3	1	7	5	3	
Myrophis punctatus	6	227.5	41.3	4		2	5	1		6	3	2	1
Palaemonetes pugio	4				4		4		4		4		
Prionotus tribulus	4	37.9	7.4	4			4		3	1	1	3	
Brevoortia patronus	3	35.7	33.8		3			3		3		1	2
Symphurus plagiusa	2	84.6	11.2	2			2			2		2	
Penaeus aztecus	1	56.9		1				1		1	1		
Penaeus setiferus	1	11.5				1		1		1		1	
Palaemonetes vulgaris	1				1			1		1	1		
Syngnathus scovelli	1	27.1		1			1		1			1	
	348			198	100	50	207	141	30	318	136	145	67
JANUARY 1979													
Anchoa mitchilli	566	40.2	9.1	115	170	281	116	450	104	462	280	277	9
Micropogonias undulatus	161	13.0	3.8	18	38	105	30	131	13	148	102	56	3
Brevoortia patronus	152	30.2	26.2	1	20	131	18	134	2	150	83	49	20
Callinectes sapidus	7	9.9	4.1			7		7		7	6	1	
Palaemonetes pugio	2					2	1	1		2		2	
Gobiesox strumosus	2	44.1	5.4	1		1		2		2	2		
Mugil cephalus	2	23.6	1.6		2			2		2		1	1
Acetes americanus	2	17.1				2	1	1		2		1	1
Palaemonetes intermedius	2			1	1			2		2		2	
Symphurus plagiusa	1	57.7			1			1		1	1		
Menidia beryllina	1	46.6			1			1		1		1	
Paralichthys albigutta	1	9.1				1		1		1		1	
Cynoscion arenarius	1	71.0				1		1		1	1		
Prionotus tribulus	1	45.5				1		1		1	1		
Anguilla rostrata	1	55.0				1		1		1		1	
Myrophis punctatus	1	254.0		1			1		1			1	
Palaemonetes kadiakensis	1			1				1		1	1		
Arius felis	1	79.1				1		1		1	1		
	905			138	233	534	167	738	120	785	478	393	34

Table 4. (Continued)

Species	Total	Mean Length	Standard Deviation	STATION: Rigolets	STATION: Chef Menteur	STATION: IHNC	TIDE: Ebb	TIDE: Flood	TIME: Day	TIME: Night	DEPTH: Bottom	DEPTH: Middle	DEPTH: Top
FEBRUARY 1979													
Anchoa mitchilli	264	32.4	8.3	43	110	111	200	64	39	215	95	94	75
Brevoortia patronus	168	20.8	8.4	109	51	8	46	122	31	137	27	36	105
Micropogonias undulatus	67	20.9	15.4	37	29	1	23	44	12	55	24	28	15
Palaemonetes pugio	30			4	22	4	24	6	3	27	2	10	16
Mugil cephalus	7	41.8	47.3	1	6		4	3		7	1		6
Gobiosoma bosci	4	21.6	7.5	2	2		2	2	2	2	2	2	
Anguilla rostrata	4	56.5	9.0		3	1		4	1	3	3		1
Syngnathus scovelli	3	87.9	17.0	1	1	1	1	2		3		2	1
Symphurus plagiusa	3	50.4	2.8	1	2		2	1		3	2	1	
Leiostomus xanthurus	3	9.9	2.8	2		1		3		3	1	1	1
Palaemonetes paludosus	2			2				2		2	1		1
Microgobius thalassinus	2	26.6	0.1	1	1		1	1	1	1		2	
Menidia beryllina	2	41.1	16.1		2		2		1	1		1	1
Palaemonetes intermedius	2			1	1		1	1		2	1	1	
Palaemonetes vulgaris	1				1		1			1		1	
Gobiesox strumosus	1	46.6			1		1			1	1		
Rhithropanopeus harrisii	1	16.8			1		1		1		1		
Callinectes sapidus	1	9.4			1		1			1	1		
Lucania parva	1	22.9			1		1			1			1
	566			204	235	127	311	255	101	465	162	179	225
MARCH 1979													
Anchoa mitchilli	583	27.6	6.2	8	12	563	15	564	9	574	337	240	6
Micropogonias undulatus	145	28.8	9.3	2	7	136	6	138	7	138	75	64	6
Brevoortia patronus	111	25.6	25.0	6	26	79	26	83	10	101	59	32	20
Callinectes sapidus	77	11.0	7.0	18	29	30	30	45	19	58	26	29	22
Paralichthys albigutta	7	10.0	0.7			7		7		7	2	5	
Palaemonetes pugio	6			2	2	2	3	3	3	3		2	4
Syngnathus scovelli	5	57.9	15.2	2	1	2	2	3	1	4	1		4
Palaemonetes paludosus	5			1	4		5			5			5
Paralichthys lethostigma	5	9.4	1.0			5		5		5	5		
Gobiosoma bosci	4	24.8	9.2		3	1	3	1	1	3	1	1	2
Palaemonetes vulgaris	3				1	2		3		3	1	2	
Myrophis punctatus	2	152.0	32.5	1	1		1	1	1	1	1	1	
Rhithropanopeus harrisii	1	5.2		1			1			1	1		
Anguilla rostrata	1	52.0		1				1		1			1
Leiostomus xanthurus	1	11.9			1		1			1			1
Microgobius thalassinus	1	29.5			1		1		1			1	
Cynoscion nebulosus	1	162.0				1		1		1		1	
	958			42	88	828	94	855	52	906	509	375	71

Table 5. ANOV for Sampling Variables of Macroplankton Collected in Tidal Passes of Lake Pontchartrain, LA, Between February 1978 and March 1979

Source of variation	d.f.	Sum of squares	Mean square	F
Total	672	6452.89		
Month	10	669.17	66.92	1.98
Station	2	82.83	41.42	1.22
Error A	20	677.10	33.86	
Depth	2	115.92	57.96	15.53**
Station x Depth	4	35.03	8.76	2.35
Error B	60	223.90		
Light	1	993.17	993.17	169.56**
Tide	1	19.46	19.46	3.32
Light x Tide	1	11.07	11.07	1.89
Station x Tide	2	146.46	73.23	12.50**
Station x Light	2	14.68	7.34	1.25
Depth x Light	2	61.64	30.82	5.26**
Depth x Tide	2	8.76	4.38	0.75
Station x Light x Tide	2	28.18	14.09	2.41
Depth x Light x Tide	2	18.24	9.12	1.56
Station x Depth x Light	4	70.93	17.73	3.03*
Station x Depth x Tide	4	41.00	10.25	1.75
Station x Depth x Light x Tide	4	31.48	7.87	1.34
Error C	547	3203.91	5.86	

* P LT .05.

** P LT .01.

The second factor that might affect the abundance of macroplankton would be any difference caused by the passes themselves. This, also, was not found to be significant. Mean catch at The Rigolets was 11; at Chef Menteur Pass it was 13; and at the IHNC it was 17 organisms per sample.

The third factor that we thought might affect movement was water depth, and this was found to have a highly significant effect ($P < .01$). Mean catch at mid-depth was 18; at the bottom it was 14; and at the top it was only 9 animals per sample. Orthogonal comparisons among the depths revealed no significant difference in catch at the middle and bottom depths but the catch at the top was significantly less ($P < .01$) than that at the deeper levels. The conclusion drawn from the data is that the middle and bottom regions of the passes are more important for larval fish movement than the surface regions.

Light level was also found to have a highly significant effect on macroplankton movement ($P < .01$). The most dramatic differences in the study were found between the catch during night (with a mean of 22 organisms per sample) and during day (with a mean of 4). Day was considered to extend from surise to sunset and night, from sunset to sunrise as calculated for the pass areas from tables published by the U.S. Naval Observatory. It is obvious from the data that there is a strong inverse relationship between light intensity and catch of macroplankton. It is uncertain at the present time if this is caused by net avoidance during the daylight or if it represents the actual behavior pattern of the species involved. Interpretation of the results by comparison with those of other investigators is difficult because day-night differences

seem to vary widely between individual studies. For example, Fore and Baxter (1972) collected more than twice as many menhaden during night sampling as during day sampling at Galveston Entrance, Texas, whereas Sabins (1973) recorded more during the daylight hours at Grand Isle, Louisiana. Two factors favor the conclusion that the difference between day and night catches is real and not a sampling artifact. The first is the high turbidity of the area, which severely limits visibility and light transmission in the waters. The second is that the fish apparently prefer the deeper regions of the water column, as discussed in the previous section. There seems to be a negative phototactic response among the species collected in the study. There was also a highly significant interaction between depth and light that further indicates non-uniform distribution of the animals with respect to these variables. Pending further research, I conclude that there is probably a difference in the movement of macroplankton through the passes between day and night.

Tidal effects were not statistically significant, although the mean catch on flood tides (20.68) was more than twice as large as that on ebb tides (7.80). This difference is readily explained if we assume that most of the fish entering the lake on a flood tide utilize it as a nursery and remain for some time. During this time their numbers are reduced by natural mortality and their ability to avoid the nets is increased by growth when they exit the lake. This explanation is somewhat simplified and would not be true for all species, particularly those that breed in Lake Pontchartrain, but it is certainly true for some of the more abundant species such as menhaden and the sciaenids.

There was a highly significant interaction ($P < .01$) between tide and station that indicates that tidal effects are not uniform among the passes. This is to be expected because the various passes have different configurations and are also different distances from the tidal influences of the Gulf of Mexico.

III. Major Species

Only those species represen ed in the collections by ten or more specimens are analyzed in detail here. Whenever the data were sufficient, the catch of an individual species for the year was analyzed in the same model used previously to evaluate the total catch. F values from the statistical analyses are presented in Table 6. Student's t-test was used to evaluate differences among mean lengths in groups of specimens. Most of the data on which the species discussions are based are presented in Tables 3 and 4.

A. *Anchoa mitchilli*

Bay anchovies were the most abundant of the species collected during the study and comprised almost two-thirds of the total catch. They occurred in all months, but were most numerous from May through October, when large numbers of postlarvae were captured. They occurred at salinities from 0.0°/₀₀ to 11.6°/₀₀ and at temperatures from 5.0°C to 32.6°C. Anchovies were also collected in Lake Pontchartrain during every month of the year and are undoubtedly one of the resident fish of the area.

The spawning period in 1978 apparently extended from May to October. The mean length of the specimens captured during these months ranged from 18.8 to 21.7 mm, whereas from November through April, mean lengths

Table 6. F Values of the Main Effects from the Split Plot Analysis of Variance for the Ten Most Abundant Species in the Macroplankton Collections from Tidal Passes of Lake Pontchartrain, LA, 1978-1979

Species	Month	Station	Depth	Light	Tide
Anchoa mitchilli	2.26	0.98	14.86**	106.97**	0.86
Brevoortia patronus	2.69*	0.60	0.38	54.11**	5.11*
Callinectes sapidus	2.75*	0.39	5.17**	37.95**	51.55**
Micropogonias undulatus	3.10*	0.13	15.52**	68.87**	10.79**
Gobiosoma bosci	1.00	0.59	4.16*	38.50**	1.29
Palaemonetes pugio	2.79*	1.05	0.10	42.38**	2.37
Microgobius gulosus	1.62	1.29	2.91	19.19**	1.14
Penaeus aztecus	4.94**	0.97	1.55	9.43**	2.01
Gobiesox strumosus	3.91**	0.85	1.06	3.02	3.82
Callianassa jamaicense	1.53	3.60*	1.17	19.52**	0.88
Degrees of freedom	11 & 21	2 & 21	2 & 64	1 & 586	1 & 586

*P < .05.

**P < .01.

ranged from 26.0 to 40.2 mm. This difference is significant at the 99% confidence level ($t = 5.5$ with 5 d.f.). Almost three times as many anchovies were caught on flood tides (7940) as on ebb tides (2657), although this varied from month to month. There was a significant difference at the 95% confidence level (one-tailed test, $t = 2.15$ with 8 d.f.) between the mean lengths compared by month of anchovies caught during the ebb tide (27.7 mm) and those caught on the flood tide (21.0 mm) during 1978. This difference is especially interesting because mesh size (1.34 mm) of the nets used during the study was too large to reliably capture anchovies below 15 mm in length. Random observations of the catches from the finer meshed net (0.363 mm) also used in the study indicated that many of the smaller larvae were passing through the coarser net.

Statistical analysis of the catch data for anchovies revealed highly significant differences ($P < .01$) among depths and in the catch between day and night. The differences in distribution of the anchovies among depths and between night and day were similar to those of the total catch.

In summary, an analysis of the data indicates differences in the size of the anchovy population in the passes during the warmer and colder months of the year. The differences in length between anchovies entering and leaving Lake Pontchartrain indicate that the lake functions as a nursery for the smaller fish, which tend to leave it as they mature. Movement of anchovies occurs mainly at night and in the middle and bottom depths of the passes.

B. Brevoortia patronus

Gulf menhaden ranked second in abundance (893) among the species collected. Almost 90% of those (798) were collected during January, February, and March, and most of the remainder were caught in April (61) and May (28). These were mainly postlarvae between 15 and 25 mm in length. Scattered collections of individual juvenile or sub-adult menhaden were made in June and July. Two postlarval and one juvenile menhaden were caught in December. Fore (1970) stated that Brevoortia patronus spawn from mid-October through March. Sabins (1973) reported postlarvae occurrence from October 1971 through April 1972, with peak catch in April, and Walker (1978) collected larval menhaden off the Louisiana coast in December 1973. Spawning apparently peaks in the winter months and begins and ends rather abruptly. Menhaden occur in tremendous numbers in Lake Pontchartrain, and it is a nursery area for immature fish. After migration into the Gulf, the adult menhaden comprise part of the largest fishery resource in the state. The mean length of the menhaden collected was 25.0 mm, with a standard deviation of 13.3 mm. B. patronus was captured at temperatures from 5.8°C to 28.0°C and salinities of 0.0‰ to 7.0‰.

Statistical analysis of the catch data revealed significant ($P < .05$) differences in the catch among months and between the two tidal flows. The variation among months reflects the seasonal nature of the menhaden immigration into the estuaries. The differences among tides, although large, may not actually be statistically valid, since three of the interactions involving tide were significant and could affect the analysis of the main tidal effects. The difference in catch between day

and night sampling periods was highly significant ($P < .01$) and reflects the 9-to-1 ratio of the night catches compared to those during the day. No significant differences were found between the passes or between the various depths.

In summary, the data support the findings of other investigators that menhaden in Louisiana waters spawn from late fall to early spring (Fore 1970, Sabins 1973, Walker 1978). Migration into Lake Pontchartrain peaks during the winter months and extends at a lesser rate through spring. Peak movement of the larval menhaden occurs at night and on flood tides.

C. Callinectes sapidus

Blue crabs ranked third in abundance and are the basis of a valuable commercial fishery in Lake Pontchartrain. They occurred in every month but were most abundant in October, when over one-third (279) of the total number for the year (864) were collected. The October increase was largely caused by an influx of megalops and first crab stage forms through the IHNC during a strong flood tide. Crabs were collected at temperatures of 6.9°C to 30.2°C and at salinities of 0.9°/₀₀ to 13.0 °/₀₀ during the year.

The mean length of crabs captured varied from a low of 8.5 mm in October (megalops larvae were not measured) to a high of 21.9 mm in August. The mean length of all the crabs collected was only 11.7 mm, with a range of 2.3 to 163.0 mm. The typical catch consisted of many small crabs with a few larger ones of various sizes. Adkins (1972) collected blue crab larvae in every month of the year and reported that female crabs in the berry stage also occurred throughout the year. Blue

crabs in Louisiana probably spawn throughout most, if not all, of the year.

Statistical analysis of the catch data for blue crabs in the split-plot model revealed significant differences among months ($P < .05$) and highly significant differences among depths, light levels, and tides ($P < .01$). There were no significant differences between the three passes. The data from Tables 3 and 4 reveal that peak movement varies seasonally and occurs on flood tides, at night, and at the middle of the passes.

D. *Micropogonias undulatus*

Atlantic croaker ranked fourth in abundance, with 1524 specimens. It is one of the most abundant fishes in Lake Pontchartrain. All of the croakers collected in the study were caught from late fall through spring. The largest catches were in February (58) and December (52) of 1978, and January (161), February (67), and March (145) of 1979, with smaller catches in April (21), May (9), and November (9). Sabins (1973) collected postlarvae from October through April at Caminada Pass, with the peak catch in November and December. The difference of a month between his data and mine may simply reflect normal yearly variation. It could also be caused by the greater distance of the Lake Pontchartrain passes from the Gulf. Sabins recorded a mean length of 12.8 mm for his specimens, whereas mine averaged 17.0 mm, indicating that they were slightly older. The specimens collected ranged in size from 4.0 mm to 67.9 mm and were collected at salinities from 0.0°/₀₀ to 8.0°/₀₀ and temperatures from 5.8°C to 30.2°C.

Statistical analysis of the catch data for croakers revealed a significant difference among months ($P < .05$) and highly significant

differences ($P < .01$) among depths, day and night, and tides. Peak movement of juvenile croakers occurs in late winter and early spring, at the middle and bottom depths of the passes, at night, and during flood tides.

E. *Gobiosoma bosci*

Naked gobies were fifth in abundance, with 336 specimens collected. They were consistently one of the dominant components of the plankton during the summer and fall. The period of greatest abundance in 1978 was from June through October, when catches ranged from 31 to 80 and averaged 58 specimens per month. The species was also present in lesser numbers during May (19), November (5), and December (14) of 1978, and February (4) and March (4) of 1979. The overall mean length of the naked gobies collected was 10.0 mm, with a range from 4.0 mm to 37.3 mm, and they occurred at salinities from 0.4°/₀₀ to 8.5°/₀₀ and in temperatures from 6.5°C to 30.2°C.

The mean size of naked gobies collected monthly from May through October 1978 ranged from 8.2 mm to 10.2 mm, whereas those collected from November 1978 through March 1979 ranged from 17.0 to 24.0 mm. A comparison of the means of the two groups of months reveals that the difference between them is highly significant ($P < .01$, $t = 7.75$ with 3 d.f.). Dawson (1966) states that the *G. bosci* population in Mississippi Sound spawns from early spring through late summer, which agrees with the size distributions observed during this study.

Nakes gobies were most abundant at Chef Menteur Pass and during flood tides although the differences among tides and passes was not statistically significant. There was a statistically significant difference

between depths ($P < .05$) and a highly significant difference between day and night catches ($P < .01$). Monthly differences were not significant.

In summary, naked gobies in the passes exhibit seasonal variations in size that are related to the spawning period. Over the year's sampling, they were most abundant at mid-depth and at night.

F. Palaemonetes pugio

Palaemonetes pugio was by far the most common of the five species of grass shrimp collected during the study, and the sixth most abundant species overall. The low-to-medium salinity environment around the passes is the preferred habitat of this species. Most of the shrimp were collected from July through October, although they occurred in all seasons. They were nearly all juveniles and probably represent a population surplus seeking available habitat. P. pugio occurred at temperatures from 6.6°C to 31.5° C and salinities from 0.0°/₀₀ to 14.0°/₀₀.

Grass shrimp were most common at the IHNC, on ebb tides, at night, and at the middle of the passes. Only the differences in catch by months ($P < .01$) were statistically significant.

G. Microgobius gulosus

Clown gobies, with 181 specimens, ranked seventh in abundance among the species collected. They occurred in the plankton from June through October, when the peak catch of 74 was recorded. Clown gobies generally occurred in the samples along with Gobiosoma bosci in approximately equal numbers. All of the specimens collected were postlarvae or small juveniles. The mean length ranged from 8.4 mm to 10.1 mm for the monthly collections; the overall mean was 9.0 mm, with a range of 6.1 mm to 14.0 mm for the year. Clown gobies probably spawn from late spring

to early fall in this area. They were collected at salinities of 2.6°/∘∘ to 9.2°/∘∘ and temperatures of 24.5° to 32.6°C during the year.

There were no significant differences in the catch between months, passes, depths, or tides despite the fact that the catch on flood tides exceeded that on ebb tides by more than eight times. A highly significant difference ($P < .01$) was found between the catches at different times of day, with the greatest numbers collected at night.

H. *Penaeus aztecus*

Brown shrimp were the eighth most abundant of the species collected and are one of the most valuable commercially. Nearly all of the 168 shrimp collected were postlarvae. Only a few large brown shrimp were captured. The scarcity of larger specimens in the collections is probably the result of their ability to avoid the small nets used. All but one of the brown shrimp collected during the study were taken in April and May. The lone exception was a sub-adult captured in December. The mean size of the shrimp collected during April was 12.7 mm and of those collected in May was 20.9 mm. The increase is probably attributable to growth. The overall mean was 19.6 mm, with a range of 10.0 mm to 56.9 mm for the year. They were collected at temperatures from 14.3°C to 25.0°C and salinities from 1.9°/∘∘ to 9.9°/∘∘.

Brown shrimp were most abundant at the IHNC, on ebb tides, and at the top of the passes, although these differences were not statistically significant. The differences in catch between months and [illegible] and night collections were highly significant ($P < .01$). [illegible] of brown shrimp occurred at night during the spring.

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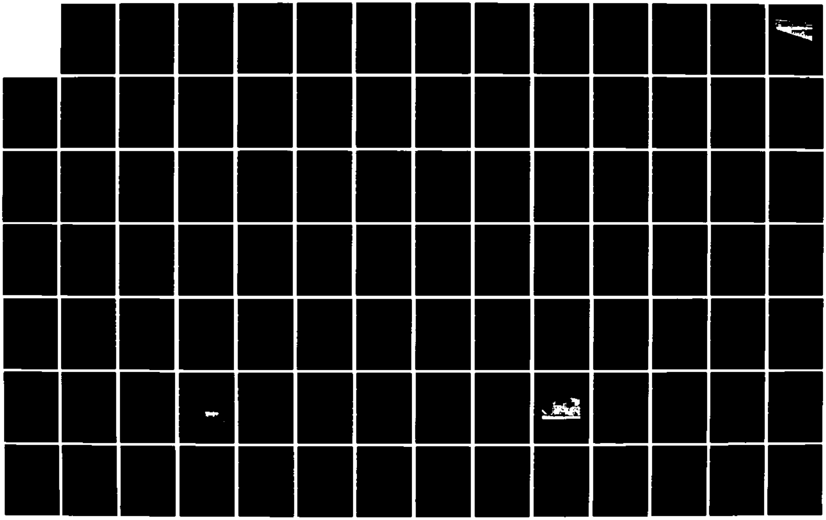

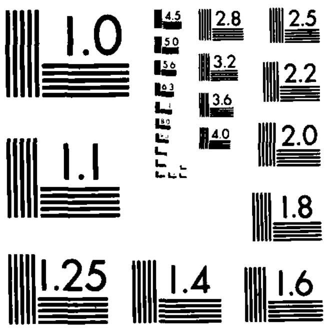

MICROCOPY RESOLUTION TEST CHART
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I. *Gobiesox strumosus*

A total of 93 skilletfish was collected during the study. All of these except three adults collected in January and February of 1979 were captured during May 1978 at either The Rigolets (64) or Chef Menteur Pass (29). They were all postlarvae of very uniform size and averaged 10.4 mm in standard length, with a range of 6.9 mm to 14.2 mm. Sabins (1972) collected skilletfish from April through June in Caminada Pass and stated that spawning occurred in March and April. The adults are fairly abundant in Lake Pontchartrain in the grass beds and around pilings or other suitable cover. The young skilletfish occurred in the collections at salinities from 3.3°/₀₀ to 5.6 °/₀₀ and at temperatures from 22.5°C to 24.7°C. The adults collected in 1979 occurred at salinities from 2.0°/₀₀ to 6.7°/₀₀ and temperatures from 6.7°C to 9.1°C. The only statistically significant difference in the catches in the split plot model was that between months.

J. *Callianassa jamaicense*

C. jamaicense was the tenth most abundant species collected during study and is probably a resident of the area. Willis (1942) and Hedgpeth (1950) recorded *C. jamaicense* from Grand Isle, Louisiana, and Aransas National Wildlife Refuge, Texas, respectively. It is a burrowing species that prefers muddy substrates in shallow to intertidal areas of estuaries. Both authors state that the animal rarely leaves its burrow, and that renders the collection of so many in open water a novelty. All but five of the 96 specimens obtained in the study were captured at night, and it is likely that the nocturnal nature of the animal has something to do with its reputation as a recluse. Specimens were captured

in April, May, June, and October in approximately equal numbers; ten were collected in November, and one each in August and December. The seasonal nature of the catch leads me to believe that it is probably related to breeding, but I have not found any information to confirm or deny this. C. jamaicense was collected at temperatures from 19.0° to 31.5°C and in salinities from 1°/₀₀ to 7°/₀₀. Statistical analysis of the catch data revealed a significant difference among stations ($P < .05$) and a highly significant difference between day and night ($P < .01$). Peak catches of C. jamaicense occurred at The Rigolets during the night.

K. Menidia beryllina

Tidewater silversides were most abundant in the collections in May, when 63 of the 76 specimens collected during the study were captured. These were mostly postlarvae and small juveniles averaging 10.3 mm. Seven were collected in August, two in September, and one in June of 1978. One sub-adult was collected in January and two in February of 1979. Gunter (1945) and Hoese (1965) have reported two spawning peaks for M. beryllina in Texas. Sabins (1973) confirmed this but noted that the fall peak was of shorter duration and lesser magnitude, which agrees with the data presented above. Silversides were collected at salinities of 1.0°/₀₀ to 5.7°/₀₀ and temperatures of 21.8° to 28.0°C.

L. Cynoscion arenarius

Sand seatrout were only moderately common in the collections (42 specimens) although they are very abundant in Lake Pontchartrain. Most of those collected were juveniles with a mean length of 20.0 mm, and it is probable that these relatively large fish were able to avoid the net

to some extent. White trout were collected from April through October; 37 of the 42 specimens were captured in April and May. This would indicate spawning in spring and summer with a spring peak. C. arenarius are believed to spawn from March through August (Gunter 1938, 1945; Reid 1955; Hoese 1965; Daniels 1977), which is in agreement with the data collected in this study. Juveniles were collected at salinities from 1.4°/₀₀ to 8.0°/₀₀ and temperatures from 19.0° to 26.5°C.

M. Trinectes maculatus

Hogchokers were collected from May through October. Larvae occurred from June through October and were most abundant in July and September. Dovel et al. (1969) found the spawning season of hogchokers in Maryland to extend from the end of May to the first week in September, with a peak in July. The mean length of the larvae collected varied from 4.9 mm in June to 10.2 mm in October. The mean length of all the larvae collected was 6.2 mm. The small size of the larvae collected suggests that they were only a few days old. Dovel et al. (1969) found evidence that hogchokers would spawn in salinities as low as 9°/₀₀. It is probable that most of the larvae collected were spawned in Lake Borgne, not far from the passes. They occurred at salinities of 1.1°/₀₀ to 11.2°/₀₀ and temperatures of 22.2° to 30.0°C.

N. Syngnathus scovelli

Small Gulf pipefish were collected sporadically from May 1978 through March 1979. The peak catch occurred in May, when 10 of the 24 were captured. S. scovelli is extremely common in the grassbeds along the shores of Lake Pontchartrain and undoubtedly breeds there as well as in Lake Borgne.

O. *Myrophis punctatus*

Speckled worm eels were collected from February through June, in August and December of 1978, and in January and March of 1979. Leptocephali were only collected from February through May. Eldred (1966) states that *M. punctatus* spawns during the fall and winter months. She collected larvae from October through March in offshore waters, with the peak catch in December and January. Sabins (1973) reported that the peak catch of leptocephali occurred in February at Grand Isle. The larvae apparently make their way from the offshore spawning area into the estuarine nursery grounds at a leisurely pace; the period of peak abundance occurs later as the distance from the Gulf increases. *M. punctatus* were collected at salinities from 1.7‰ to 9.4‰ and temperatures from 8.3° to 28.0°C.

P. *Penaeus setiferus*

Only 15 white shrimp postlarvae were taken during the study. The reasons for their relative scarcity are not known, but trawl sampling in Lakes Pontchartrain and Borgne also produced few white shrimp, and conversations with commercial fishermen in the area revealed that they considered the catch to be poor in 1978. Postlarvae were collected from July through December; the maximum monthly catch of four occurred in October.

Q. *Rhithropanopeus harrisii*

Mud crabs are one of the most abundant animals in the environment surrounding the passes. Unlike the blue crab, they are unable to swim. The 12 specimens captured were probably clinging to pieces of detritus carried into the net by the current.

R. Syngnathus louisianae

The chain pipefish is much less abundant in Lake Pontchartrain than S. scovelli because it prefers more saline conditions. The 11 specimens collected during May and July were probably immigrants from Lake Borgne. Dawson (1972) has recorded this species from offshore Gulf waters, and it seems to be more nektonic than most of the other inshore species of pipefish.

S. Symphurus plagiusa

Juveniles of the blackcheek tonguefish were collected in small numbers during all seasons. No more than three were collected in any one month. Hoese and Moore (1977) describe the habitat of this species as shallow, inshore waters. It is fairly common, although not abundant, in both Lake Pontchartrain and Lake Borgne.

T. Microgobius thalassinus

The green goby is considered to be a rather uncommon species (Dawson 1969), and little is known of its biology. Schwartz (1971) describes its preferred habitat in Chesapeake Bay as the insides of sponges and bryozoans.

U. Membras martinica

Ten rough silversides were collected during September, October, and November. These were all moderately large fish with a mean length of 67.8 mm. M. martinica and Strongylura marina were very abundant on the surface of the passes, and often thousands could be seen feeding in the area illuminated by the lights of the boat.

DISCUSSION

This study was designed to provide information on the movement of macroplankton into and out of Lake Pontchartrain and to evaluate the effect of some factors on that movement. Comparison of Tables 5 and 6 reveals some differences and similarities between the overall catch and the catch of the individual species. Differences between months were not significant for the overall catch but they were for six of the top ten species. Previous investigators (Hoese 1965, Sabins and Truesdale 1974) have observed that there are distinct seasonal assemblages of immature fishes that they described as "coldwater" and "warmwater." The coldwater assemblage (i.e., fish that spawn during the winter months) in the Lake Pontchartrain passes occurred from November through April and was composed mainly of Brevoortia patronus, Micropogonias undulatus, and juvenile to adult Anchoa mitchilli. The warmwater assemblage occurred from May through October and was dominated by larval Anchoa mitchilli, Callinectes sapidus, Gobiosoma bosci, Microgobius gulosus, and Palaemonetes pugio. Callianassa jamaicense probably also belongs to this group, although it occurred mainly in spring and fall and was rarely collected during the summer. There was also a third assemblage that occurred only during the spring months of April and May and it was composed of Gobiesox strumosus and Penaeus aztecus. There is some overlapping among these assemblages, so that seasonal differences among the total catch are minimized.

Neither the statistical analysis nor the raw data revealed major differences among the catch at the three passes. Only Callianassa jamaicense showed a statistically different distribution among the passes. This was somewhat surprising because the two natural passes are

much larger and deeper than the IHNC. The implication is that an artificially constructed pass is functionally indistinguishable from a natural pass to the larval fish and crustaceans.

The differences among the three depths sampled were significant for the overall catch and for four of the five most abundant species but not for any of the five next most abundant ones. Most species were more abundant at mid-depth of the passes. Of the four species that showed significant differences in distribution with respect to depth, only Micropogonias undulatus was most abundant at the bottom of the passes. No species of which more than one specimen was collected occurred at only one depth. The possibility exists that the relatively lower catch at the surface could be a sampling artifact caused by the nearness of the net to the noise and lights of the boat. Evidence against this is that six of the ten species exhibited a random distribution with respect to depth and several were actually more abundant at the surface.

The difference between the day catch and the night catch was the most dramatic of those observed during the study. It was highly significant for the overall catch and for nine of the ten most abundant species. Eleven of the 35 species represented in the collections by more than one specimen occurred only at night; none occurred only during the day. Some of the observed difference may be caused by increased net avoidance during the day, but I doubt that this phenomenon alone could produce the observed disparity in the catches, especially since the waters of the passes are highly turbid and would severely limit light penetration. There seems to be a real difference in the movement of the larval fish and crustaceans with respect to day and night.

Tidal differences were not statistically significant for the overall catch but they were for three of the four most abundant species--menhaden, blue crabs, and croakers. All of these were most abundant on flood tides, and they demonstrate the pattern that one would expect for a species utilizing an estuary as a nursery. More puzzling is the fact that the other species did not exhibit definite movement into Lake Pontchartrain. Sabins and Truesdale (1974) also reported large catches of some species on ebb tides when they should not have occurred. This phenomenon is not readily explainable. It may be that the inshore movement of larval fish and crustaceans is more dependent on favorable tidal conditions than has been supposed. If the animals do not penetrate far enough into the estuary on the flood tides to be beyond the influence of the ebb currents, then they may be swept back out again. It may require several trips through the passes before they are able to advance far enough into the lake to escape the effect of the ebb currents. If the transport mechanism does in fact operate in this fashion, then any alteration of the environment that would affect the survival of the macroplankters while they are in the passes could have a more severe impact than would be predicted on the basis of a one-time exposure to it. Such alterations would include restrictions in the channel size that produce significant turbulence (such as bridges, locks, or floodgates as well as power plant water intakes) that would directly remove a percentage of the plankton in the water on each tidal cycle. The diel differences in the catch suggest that such effects could be minimized by restricting operation to the daylight hours when macroplankton is least abundant.

The importance of the passes is obvious from the list of species that use them as an entrance to the Lake Pontchartrain nursery area. Major commercial and sport species collected in the passes as larvae or juveniles include menhaden, blue crabs, Atlantic croaker, brown and white shrimp, seatrout, spot, and flounder. None of these species spawn in Lake Pontchartrain but all utilize it during part of their life cycle.

SUMMARY

The numbers and species of macroplankters collected during the study were affected by seasons, light level, tides, and sampling depth. The greatest numbers of specimens were collected at night, during flood tides, and at mid-depth of the passes. There were few differences in the total collections at the three passes for the year. The IHNC was considered to be functionally similar to The Rigolets and Chef Menteur Pass with respect to macroplankton usage.

Collections of macroplankton varied seasonally in numbers and species composition. Catches were highest in May, June, and October. *Anchoa mitchilli* was the dominant species and composed nearly two-thirds of the total number or organisms collected. The winter and early spring collections were dominated by *Anchoa mitchilli*, *Brevoortia patronus*, *Micropogonias undulatus*, and *Callinectes sapidus*. Species collected mainly in the spring were *Penaeus aztecus* and *Gobiesox strumosus*. Collections from spring through late fall were dominated by larval *Anchoa mitchilli*, *Callinectes sapidus*, *Gobiosoma bosci*, and *Microgobius gulosus*. Migration through the passes is essential to the maintenance of populations of these species in Lake Pontchartrain.

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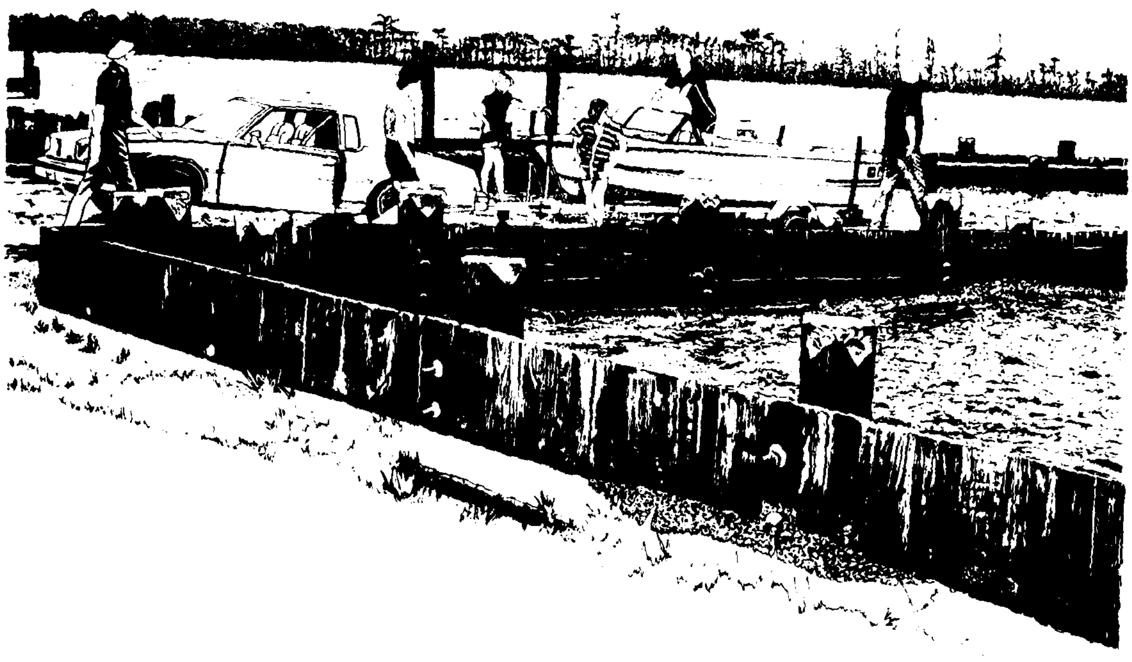

Boat launch near Madisonville

Chapter 16

SELECTED COMMERCIAL FISH AND SHELLFISH DATA FROM LAKE PONTCHARTRAIN, LOUISIANA, DURING 1963-1975, SOME INFLUENCING FACTORS, AND POSSIBLE TRENDS

by

Bruce A. Thompson
and
James H. Stone

ABSTRACT

The blue crab dominates the commercial fishery of Lake Pontchartrain. During the 13-year period of 1963 to 1975, blue crab accounted for, on the average, 67% of the value and 79% of the volume of Lake Pontchartrain's catch. Yearly harvest varies between 45% and 96% of total catch.

Shrimp and fishes account for, on the average, 19% and 14%, respectively, of the value and 10% each of the volume of the lake's catch. Yearly shrimp harvest varies between zero and 41% of total catch.

It is likely that extreme variations in salinity and temperature cause commercial catches to vary as widely as they do. However, other factors such as turbidity, poor water quality, shoreline alterations, and loss of grassbeds probably adversely affect fish yields.

Lakes Pontchartrain and Maurepas account for about 9% of Louisiana's crab harvest and 0.13% and 0.10%, respectively, of the state's shrimp and fish harvest. However, the nursery potential of Lakes Pontchartrain and Maurepas amounts to about 20 x 10^3 km^2 (1/2 million acres) or about 30% of Hydrologic Unit I and about 15% of the state's total.

Systematic and significant trends are apparent in the 1963-75 fish harvest data from Lake Pontchartrain; however, the factors that influence these trends cannot be identified at this time.

INTRODUCTION

Lake Pontchartrain is part of a large, estuarine complex that has a total area of approximately 1632 km^2. The area has been described in detail several times (Darnell 1958, 1962a; Tarver and Dugas 1973; Montz 1978). Darnell (1962a) and Saucier (1963) discussed the ecological and geological history of the basins.

Commercial fishery statistics are presented in this report for Lakes Pontchartrain and Maurepas for the period 1963 to 1975. In addition, data from 1976 and 1977 (combined with the catch from Lake Borgne) are given. These data were obtained from the New Orleans, Louisiana, office of the National Marine Fisheries Service and the draft report to the Corps of Engineers (COE 1974).

The data include weight (traditionally presented in English Units, which we will follow)[a] and monetary value figures for those species recorded for Lakes Pontchartrain and Maurepas in the commercial catch. Certain species appear irregularly from year to year. This is most likely a statistical sampling error, and probably a fishery exists for these species every year. The figures do not include catches from private commercial fishermen or sportsmen, so these statistics do not reflect the total fishing pressure on the Lake Pontchartrain/Maurepas populations.

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[a] 1.0 lb = 0.45 kg.

This report analyzes the actual commercial catch figures, discusses some of the factors that possibly influence the success of commercial fishing, and cites some possible trends for the Lake Pontchartrain fishery.

OBJECTIVES

The objective of this report is to determine from available records the quality and quantity of existing commercial fishery resources of Lake Pontchartrain and its surrounding wetlands.

DATA PRESENTATION

Crabs, shrimp, and catfish are the dominant species of Lake Pontchartrain's commercial fishery. Table 1 gives data ranked in terms of harvest volume and harvest value. The harvest volume of crab is always ranked first (13 out of the 13 years); its value is ranked first during 11 of the 13 years. The value of shrimp harvest ranked first for only 2 of the 13 years; however, shrimp volume and value are usually ranked second, 6 and 7 out of the 13 years, respectively. Catfish ranked second in terms of volume and value during 5 of the 13 years. Seatrout generally ranked third in terms of volume and value, 6 years out of the 13. A more detailed analysis is given below in terms of crabs, shrimp, and fish.

I. Crabs

The crab fishery in Lakes Pontchartrain and Maurepas exploits the blue crab, *Callinectes sapidus*. For the 13 years between 1963 and 1975, the poundage and monetary value of blue crabs far exceeded the other fishery resources (except 1966, 1970, and 1972, when the monetary value

Table 1. Data Ranked in Terms of Harvest Volume and Value for Commercial Fishery of Lake Pontchartrain, LA, Between 1963 and 1975*

Rank	Volume		Value	
1st	Crab	13 of 13	Crab	11 of 13
			Shrimp	2 of 13
2nd	Shrimp	7 of 13	Shrimp	6 of 13
	Catfish	5 of 13	Catfish	5 of 13
	Shad	1 of 13	Crab	2 of 13
3rd	Catfish	6 of 13	Catfish	5 of 13
	Seatrout	6 of 13	Seatrout	6 of 13
	Sheepshead	1 of 13	Sheepshead	1 of 13
			Shrimp	1 of 13

*Based on data from Table 2.

of shrimp was greatest). The catch, by weight, ranged from 325,800 lbs (1965) to 2,028,300 lbs (1973) and averaged 806,631 lbs. The total catch for the 13-year period was 10,486,200 lbs. The percentage of catch ranged from 45.1% (1970) to 96.4% (1973) and averaged 79.1% of the total commercial catch. The value of the crab catch varied from $41,163 (1966) to $359,446 (1973) and averaged $129,031. The total value for the crabs in this 13-year period was $1,677,407.

Tables 2 and 3 present the catch data for blue crabs for the period 1963 to 1975.

II. Shrimp

The shrimp fishery in Lake Pontchartrain is made up predominantly of two species, *Penaeus aztecus* (brown shrimp) and *P. setiferus* (white shrimp). The low salinity of the lake probably prohibits the presence of a third commercial species, *P. duorarum* (pink shrimp).

The shrimp catch (by weight) ranged from 5,000 lbs (1965) to 409,000 lbs (1970) and averaged 129,100 for 10 years. In 1963, 1964, and 1967, no shrimp catch figures were recorded. Whether this indicates very poor shrimping years or missing data cannot be shown from the original NMF figures. The total catch for the 10 years is 1,129,000 lbs. The percentage of catch ranges from 0.5% (1973) to 40.8% (1970) and averages 13.3% of the total commercial catch.

The value of the shrimp catch varied from $2,250 (1965) to $138,576 (1972) and averaged $45,550. The total value for the shrimp catch for the 10 years was $455,503. During 1970 and 1972 the shrimp catch was worth more than the crab catch even though the crab catch weighed more. In 1965, 1973, and 1975, the shrimp catch figures, both in total weight

Table 2. Commercial Catches of Fish, Reptiles, and Invertebrates in Lake Pontchartrain and Lake Maurepas from 1963 to 1975*

	1963				1964				1965			
	Pounds	Rank	$ value	Rank	Pounds	Rank	$ value	Rank	Pounds	Rank	$ value	Rank
Fish												
Black Drum	3,500	4	280	8	1,500	5	120	5	1,500	6	150	6
Buffalo	—		—		300	10	30	10	200	10	24	10
Catfish and Bullhead	95,200	2	19,040	2	99,500	2	22,565	2	64,500	2	18,060	2
Croaker	—		—		—		—		—		—	
Flounder	2,400	7	432	7	500	8	100	6	300	9	75	8
Freshwater Sheepshead (= Freshwater Drum)	7,300	3	876	3	—		—		—		—	
Gar	1,900	10	95	10	1,100	6	55	8	1,300	7	78	7
King Whiting and Kingfish	—		—		—		—		—		—	
Red Drum	2,400	7	500	5	4,200	4	756	4	5,700	4	1,083	5
Seacatfish	—		—		400	9	32	9	—		—	
Seatrout, Spotted	2,400	7	600	4	14,500	3	3,625	3	20,500	3	5,125	3
Seatrout, White	—		—		—		—		—		—	
Shad	—		—		—		—		—		—	
Sheepshead	2,100	9	168	9	1,000	7	100	6	600	8	60	9
Unclassified for ind.	—		—		—		—		—		—	
Reptiles												
Snapping Turtle	3,000	5	450	6	—		—		—		—	
Invertebrates												
Blue Crab (Hard)	939,800 }	1	58,394 }	1	503,000 }	1	40,240 }	1	296,800 }	1	24,770 }	1
Blue Crab (Soft)	105,500 }		52,750 }		52,600 }		31,580 }		29,000 }		22,400 }	
Shrimp (Heads on)	—		—		—		—		5,000	5	2,250	4
TOTALS	1,165,500		133,585		678,600		99,203		425,400		74,075	

*Data modified from National Marine Fisheries Service, New Orleans, LA Office.

Table 2. (Continued)

	1966				1967				1968			
	Pounds	Rank	$ value	Rank	Pounds	Rank	$ value	Rank	Pounds	Rank	$ value	Rank
Fish												
Black Drum	1,100	7	89	7	1,200	6	79	6	4,400	6	378	7
Buffalo	300	9	39	8	100	7	13	8	---		---	
Catfish and Bullhead	30,900	3	8,587	3	29,500	2	8,224	2	28,800	3	8,251	3
Croaker	---		---		---		---		---		---	
Flounder	100	11	25	10	100	7	17	7	500	8	82	8
Freshwater Sheepshead (= Freshwater Drum)	---		---		---		---		---		---	
Gar	400	8	30	9	---		---		---		---	
King Whiting and Kingfish	---		---		---		---		---		---	
Red Drum	5,300	6	1,119	6	9,200	5	1,534	4	4,100	7	558	6
Seacatfish	12,000	5	1,185	5	10,300	4	896	5	8,200	4	732	5
Seatrout, Spotted	19,700	4	4,701	4	23,100	3	4,890	3	6,000	5	1,502	4
Seatrout, White	---		---		---		---		---		---	
Shad	---		---		---		---		---		---	
Sheepshead	200	10	25	10	---		---		---		---	
Unclassified for ind.	---		---		---		---		---		---	
Reptiles												
Snapping Turtle	---		---		---		---		---		---	
Invertebrates												
Blue Crab (Hard)	332,400	1	24,686	2	583,500	1	39,794	1	480,100	1	39,960	1
Blue Crab (Soft)	24,800		16,477		22,400		18,532		36,000		29,030	
Shrimp (Heads on)	107,900	2	51,115	1	---		---		60,000	2	37,403	2
TOTALS	535,100		108,078		679,400		73,979		628,100		117,896	

Table 2. (Continued)

	1969 Pounds	1969 Rank	1969 $ value	1969 Rank	1970 Pounds	1970 Rank	1970 $ value	1970 Rank	1971 Pounds	1971 Rank	1971 $ value	1971 Rank
Fish												
Black Drum	20,200	6	1,349	8	17,600	7	1,355	7	3,200	7	281	9
Buffalo	---		---		---		---		4,000	6	572	6
Catfish and Bullhead	39,000	3	10,998	3	30,200	3	8,697	3	12,100	3	3,934	3
Croaker	---		---		---		---		---		---	
Flounder	4,500	9	730	9	3,500	9	585	9	700	12	113	12
Freshwater Sheepshead (= Freshwater Drum)	---		---		---		---		1,000	11	116	11
Gar	28,300	4	2,184	6	25,700	4	1,773	6	---		---	
King Whiting and Kingfish	---		---		---		---		---		---	
Red Drum	22,400	5	3,250	5	20,400	6	3,305	5	2,600	9	514	7
Seacatfish	16,700	8	1,573	7	14,600	8	1,008	8	8,200	4	1,036	5
Seatrout, Spotted	18,200	7	5,432	4	23,100	5	6,422	4	5,700	5	2,003	4
Seatrout, White	4,000	10	413	10	3,200	10	249	10	2,900	8	384	8
Shad	---		---		---		---		---		---	
Sheepshead	600	11	58	11	1,200	11	139	11	1,800	10	145	10
Unclassified for ind.	---		---		---		---		---		---	
Reptiles												
Snapping Turtle	---		---		---		---		---		---	
Invertebrates												
Blue Crab (Hard)	532,400	1	49,344	1	440,600	1	40,099	2	1,078,100	1	144,727	1
Blue Crab (Soft)	45,400		37,245		11,000		9,746		42,200		38,397	
Shrimp (Heads on)	73,600	2	35,846	2	409,000	2	92,428	1	154,600	2	37,746	2
TOTALS	805,300		148,422		1,002,100		165,806		1,317,100		225,968	

Table 2. (Continued)

	1972				1973				1974				1975			
	Pounds	Rank	$ value	Rank	Pounds	Rank	$ value	Rank	Pounds	Rank	$ value	Rank	Pounds	Rank	$ value	Rank
Fish																
Black Drum	10,200	5	1,050	6	1,400	8	117	9	2,400	7	332	7	1,600	8	258	8
Buffalo	---		---		---		---		200	13	30	13	---		---	
Catfish and Bullhead	4,400	8	1,600	5	32,300	2	12,425	2	5,000	6	2,071	5	9,100	3	3,895	4
Croaker	4,800	7	522	8	100	10	12	10	---		---		200	12	17	13
Flounder	200	11	30	11	500	9	113	9	700	10	175	10	300	11	65	11
Freshwater Sheepshead (= Freshwater Drum)	---		---		---		---		500	11	75	11	100	14	11	15
Gar	---		---		4,500	6	450	6	2,300	8	299	8	800	10	106	10
King Whiting and Kingfish	100	12	10	12	---		---		---		---		200	12	27	12
Red Drum	11,500	4	2,252	4	6,900	5	1,931	5	7,800	5	2,215	4	4,700	6	1,469	5
Seacatfish	1,800	10	270	10	---		---		---		---		1,200	9	145	9
Seatrout, Spotted	42,000	3	15,230	3	16,700	3	7,535	4	16,800	3	6,480	3	8,700	4	4,016	3
Seatrout, White	4,900	6	705	7	1,900	7	278	7	1,600	9	213	9	3,400	7	543	7
Shad	---		---		---		---		---		---		25,000	2	750	6
Sheepshead	4,000	9	474	9	---		---		400	12	48	12	100	14	12	14
Unclassified for ind.	---		---		---		---		15,000	4	750	6	---		---	
Reptiles																
Snapping Turtle	---		---		---		---		---		---		---		---	
Invertebrates																
Blue Crab (Hard)	671,900	1	90,211	2	1,973,600	1	296,882	1	1,139,800	1	196,446	1	986,800	1	180,005	1
Blue Crab (Soft)	38,600		41,748		54,700		62,564		34,600		48,440		30,600		42,940	
Shrimp (Heads on)	335,800	2	138,576	1	10,800	2	9,851	3	128,600	2	41,855	2	5,700	5	8,433	2
TOTALS	1,130,200		292,678		2,103,400		392,218		1,355,700		299,429		1,078,500		242,692	

Table 3. Commercial Catch Totals of Fish, Crab, and Shrimp in Lakes Pontchartrain and Maurepas from 1963 to 1975

Year	Catch	Pounds	Total Pounds	Value	Total Value	%* Pounds	%* $ Value	Year Rank Pounds	Year Rank $ Value
1963	Fish	117,200		$ 21,991		10.1	16.5	4	8
	Crab	1,045,300		111,144		90.0	82.2		
	Shrimp	---		—		—	—		
			1,162,500		$133,135				
1964	Fish	123,000		27,383		18.1	27.6	10	11
	Crab	555,600		71,820		81.9	72.4		
	Shrimp	---		—		—	—		
			678,600		$ 99,203				
1965	Fish	94,600		24,655		22.2	33.3	13	12
	Crab	325,800		47,170		76.6	63.7		
	Shrimp	5,000		2,250		1.2	3.0		
			425,400		$ 74,075				
1966	Fish	70,000		15,800		13.1	14.6	12	10
	Crab	357,200		41,163		66.8	38.1		
	Shrimp	107,900		51,115		20.1	47.3		
			535,100		$108,078				
1967	Fish	73,500		15,653		10.8	21.2	9	13
	Crab	605,900		58,326		89.2	78.8		
	Shrimp	—		—		—	—		
			679,400		$ 73,979				
1968	Fish	52,000		11,503		8.3	9.8	11	9
	Crab	516,100		68,990		82.2	58.5		
	Shrimp	60,000		37,403		9.5	31.7		
			628,100		$117,896				
1969	Fish	153,900		25,987		19.1	17.5	8	7
	Crab	557,800		86,589		71.7	58.3		
	Shrimp	73,600		35,846		9.2	24.2		
			805,300		$148,422				

*Snapping turtle not included.

Data from National Marine Fisheries Service, Atmospheric Administration, New Orleans Office, totaled from Table 2 (cf. Tables 9 and 10 for state landings).

Table 3. (Continued)

Year	Catch	Pounds	Total Pounds	Value	Total Value	%* Pounds	%* $ Value	Year Rank Pounds	Year Rank $ Value
1970	Fish	141,500		23,533		14.1	14.2	7	6
	Crab	451,600		49,845		45.1	30.1		
	Shrimp	409,000		92,428		40.8	55.7		
			1,002,100		$165,806				
1971	Fish	42,200		9,098		3.2	4.0	3	5
	Crab	1,120,300		183,124		85.1	79.6		
	Shrimp	154,600		37,746		11.7	16.4		
			1,317,100		$229,968				
1972	Fish	83,900		22,143		7.4	7.6	5	3
	Crab	710,500		131,959		62.9	45.1		
	Shrimp	335,800		138,576		29.7	47.3		
			1,130,200		$292,678				
1973	Fish	64,300		22,921		3.1	5.8	1	1
	Crab	2,028,300		359,446		96.4	91.7		
	Shrimp	10,800		9,851		.5	2.5		
			2,103,400		$392,218				
1974	Fish	52,700		12,688		3.9	4.2	2	2
	Crab	1,174,400		244,886		86.6	81.8		
	Shrimp	128,600		41,855		9.5	14.0		
			1,355,700		$299,429				
1975	Fish	55,400		11,314		5.1	4.7	6	4
	Crab	1,017,400		222,945		94.3	91.9		
	Shrimp	5,700		8,433		.6	3.4		
			1,078,500		$242,692				

*Snapping turtle not included.

Data from National Marine Fisheries Service, Atmospheric Administration, New Orleans Office, totaled from Table 2. (cf. Tables 9 and 10 for state landings).

and monetary value, were extremely low. Several possibilities to explain these declines are discussed below.

Tables 2 and 3 present the commercial catch data for Lake Pontchartrain for 10 of the 13 years covered in this analysis.

III. Fish

A few species dominate the commercial fishing efforts in Lakes Pontchartrain and Maurepas. Total catch ranged from 42,200 lbs (1971) to 153,900 lbs (1969) and averaged 86,477 lbs. The total catch for the 13-year period was 1,124,200 lbs. The percentage of catch ranged from 3.1% (1973) to 22.2% (1965) and averaged 10.7% of the total commercial catch for the lakes. The value of the fish catch varied from $7,098 (1971) to $27,383 (1964) and averaged $18,821. The total value for the fish catch in this 13-year period is $244,669.

Table 2 lists the individual species of fish present for the 13-year period. Table 3 presents catch and monetary values for the total fish take from the lake area. The Lake Pontchartrain commercial fishery is dominated overall by catfishes and spotted seatrout. Table 4 reflects the importance of freshwater catfish and drum families in the fish community.

For 7 of the 13 years, the fish catch ranked second in weight behind the blue crab; in 6 of the years, the fish catch ranked third behind both crab and shrimp.

In 1974 and 1975, unclassified catch (maybe equivalent of shad) and shad accounted for 28% and 45.1% of the fish catch by weight, respectively. However, these had little monetary value and were 5.9% and 6.6% of the total value of the fish catch. With the inclusion of these rough data

Table 4. Dominant Fish Groups in Lake Pontchartrain/Lake Maurepas Commercial Catch, 1963-1975*

Year	Fish Group	% Fish Catch	Pounds	% Fish Value	$ Value
1963	Catfishes	81.2	95,200	86.6	19,040
1964	Catfishes	80.9	99,500	82.4	22,565
1965	Catfishes	68.2	64,500	73.3	18,060
1966	Catfishes	44.1	30,900	54.2	8,567
1967	Catfishes	40.1	29,500	52.5	8,224
1968	Catfishes	55.4	28,800	71.7	8,251
1969	Catfishes	25.3	39,000	42.3	10,998
1970	Catfishes	21.3	30,200	37.0	8,697
1971	Catfishes	28.7	12,100	43.2	3,934
1972	Spotted Sea Trout	50.1	42,000	68.8	15,230
1973	Catfishes	50.2	32,300	54.[illegible]	12,425
1974	Spotted Sea Trout	31.9	16,800	51.1	6,480
1975	Catfishes	16.4	9,100	34.4	3,895

*Data taken from Table 2.

for only two years, it is difficult to assess the importance of these fish in the overall fishery.

DISCUSSION

Barrett and Gillespie (1973) believe that the most critical factors influencing shrimp production along the Louisiana coast are:

1) Temperature - the surface water temperature (below 20° C) could be used to predict brown shrimp production (Table 5).
2) Salinity - the amount of rainfall (Table 5) and river discharge is inversely correlated with catch success for both brown and white shrimps.

They also considered other factors such as water fertility and turbidity, competition, predation, substrate, unseasonal meteorological conditions, and man-made environmental modifications.

Adkins (1972) reported that the major influences on the blue crab in Louisiana are man-made. Estuarine alterations caused by dredging, industrial pollution, agricultural run-off, and domestic and industrial sewage were discussed as major factors affecting the success of the blue crab populations. Most of these factors also influence the commercial fish catches.

In the Lake Pontchartrain-Maurepas complex, factors that affect the commercial fishing/crabbing/shrimping industry can be classified as follows:

I. <u>Natural Environmental Factors</u>

1. Rainfall
2. Salinity
3. Temperature
4. Turbidity
5. Substrate

Table 5. Commercial Catches of Lake Pontchartrain and Maurepas with Average Annual Rainfall[1] and Temperature[2] from 1963 to 1975

	Fish[3]	Crab[3]	Shrimp[3]	Rainfall (SE)	dev.	Rainfall (EC)	dev.	Temp. (SE)	dev.	Temp. (EC)	dev.
1963	117,200	1,045,300	—	51.59	-10.81	44.36	-15.94	68.5	-1.1	66.5	-0.8
1964	123,000	555,600	—	63.74	1.34	66.84	6.54	68.8	-0.8	66.9	-0.4
1965	94,600	325,800	5,000	56.55	-4.81	49.13	-10.80	69.4	-0.2	67.7	0.4
1966	70,000	357,200	107,900	76.04	14.68	65.10	5.17	67.9	-1.7	66.0	-1.3
1967	73,500	605,900	—	60.76	-.60	56.92	-3.01	68.9	-0.9	66.6	-0.7
1968	52,000	516,100	60,000	44.95	-16.41	48.81	-11.12	67.5	-2.1	65.4	-1.9
1969	153,900	577,800	73,600	53.62	-7.74	54.80	-5.13	68.1	-1.5	66.4	-0.9
1970	141,500	451,600	409,000	55.23	-6.13	57.39	-2.54	67.9	-1.7	66.2	-1.1
1971	42,200	1,120,300	154,600	59.38	-1.98	60.09	.16	69.3	-0.3	67.4	0.1
1972	83,900	710,500	335,800	64.38	3.02	66.36	6.43	69.6	0.0	67.9	0.6
1973	64,300	2,028,300	10,800	75.58	15.26	76.73	16.80	69.0	-0.6	67.2	-0.1
1974	52,700	1,174,400	128,600	59.90	-1.23	68.77	9.07	69.9	0.7	67.0	0.0
1975	55,400	1,017,400	5,700	72.09	10.96	71.19	11.49	69.0	-0.2	66.9	-0.1

1, 2 Rainfall (inches) and temperature (°F) recorded by National Weather Service, National Oceanic and Atmospheric Administration for Southeast (SE) and East Central (EC) sections, Louisiana.

3 Poundage taken from Table 2.

II. Natural Biological Factors

1. Competition
2. Predation

III. Man-Induced Factors

1. Mississippi River-Gulf Outlet (MRGO)
2. Opening of Bonnet Carre Floodway
3. Dredging
4. Shore Alteration (seawalls, levees, draining, filling, etc.)
5. Loss of Grassbeds
6. Population Growth and City Effects
7. Petroleum Industry Activities

IV. Economic Factors

1. Inflation
2. Loss of Market
3. Changes in Labor Market

The populations of commercial species have, through the geologic changes in the Lake Pontchartrain-Maurepas estuary, become adjusted to a natural range of changes in the lakes (Darnell 1962a). Man, however, has introduced new factors to which the lake biota may not be able to adjust. Group I and II are natural factors, and Group III primarily affects the commercial species through temporary and permanent changes in Groups I and II. Factors of Group IV are, to a certain extent, independent of the first three groups. Although there is considerable interplay among the natural factors, their basic influence can be assessed separately, as discussed by Recksiek and McCleave (1973).

I. Natural Factors

A. Rainfall

Major deviations from the norm can result in good or poor catches. The 1965 Lake Pontchartrain shrimp catch may have been depressed by Hurricane Betsy. Gunter and Edwards (1969), Gunter and Hildebrand (1954),

and Hildebrand and Gunter (1953) have discussed the inverse relationship between rainfall and shrimp production via salinity changes.

Mean deviation of annual rainfall is compared to yearly catches of fish, crab, and shrimp in Table 5 and Figures 1-3. Correlation coefficients (r) ranged from -.35 to .53 for a comparison between commercial catches and average annual rainfall in eastcentral and southeastern Louisiana (Not significant @ 95%). It is not possible to evaluate the success of the commercial fishery from the rainfall because there are no significant trends between wet and dry years and reported catches.

B. Salinity

The adjustment of the Lake Pontchartrain-Maurepas biota to changes in salinity may be the most important factor in determining the success of the commercial catch. Table 6 lists salinity figures for Lake Pontchartrain from previous studies conducted between 1953 and 1978. There are considerable fluctuations in the average annual salinity but there is no evident trend towards either a lower or higher salinity regime.

Classifications of organisms based on their salinity tolerance have been attempted many times in the past. Gunter (1938a and b, 1942, 1945, 1947, 1956a and b, 1957, 1961a and b, and 1967) and Gunter and Shell (1958) have discussed at length various aspects of the effect of salinity on fishes. Bailey et al. (1954) and Darnell (1962a) grouped different components of the fish fauna they investigated by their salinity tolerance. Darnell (1962b) discussed some of these aspects for the Lake Pontchartrain fauna.

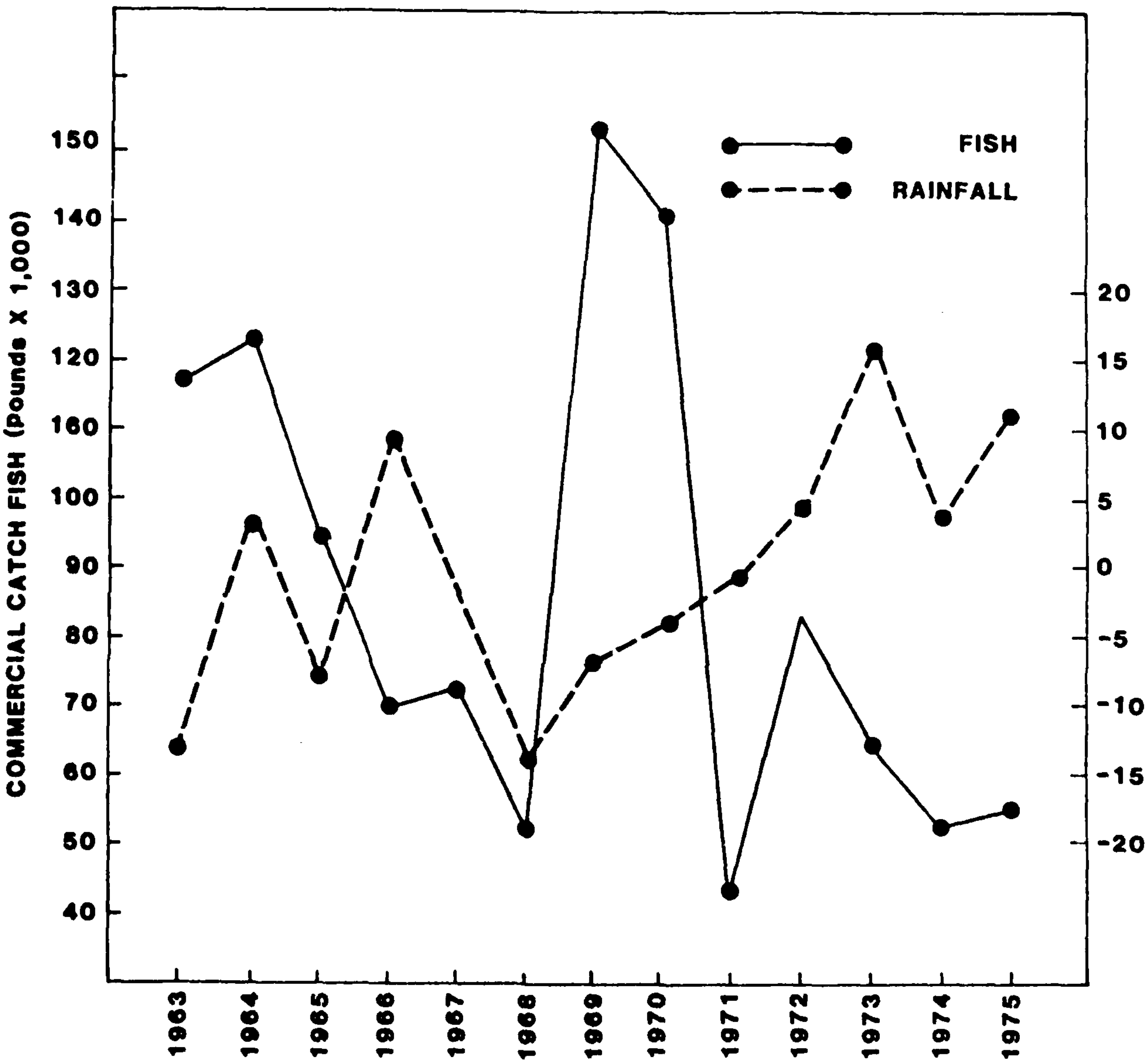


Figure 1. Comparison between commercial fish catch in Lake Pontchartrain, LA, and mean deviation of annual rainfall, 1963-1975.

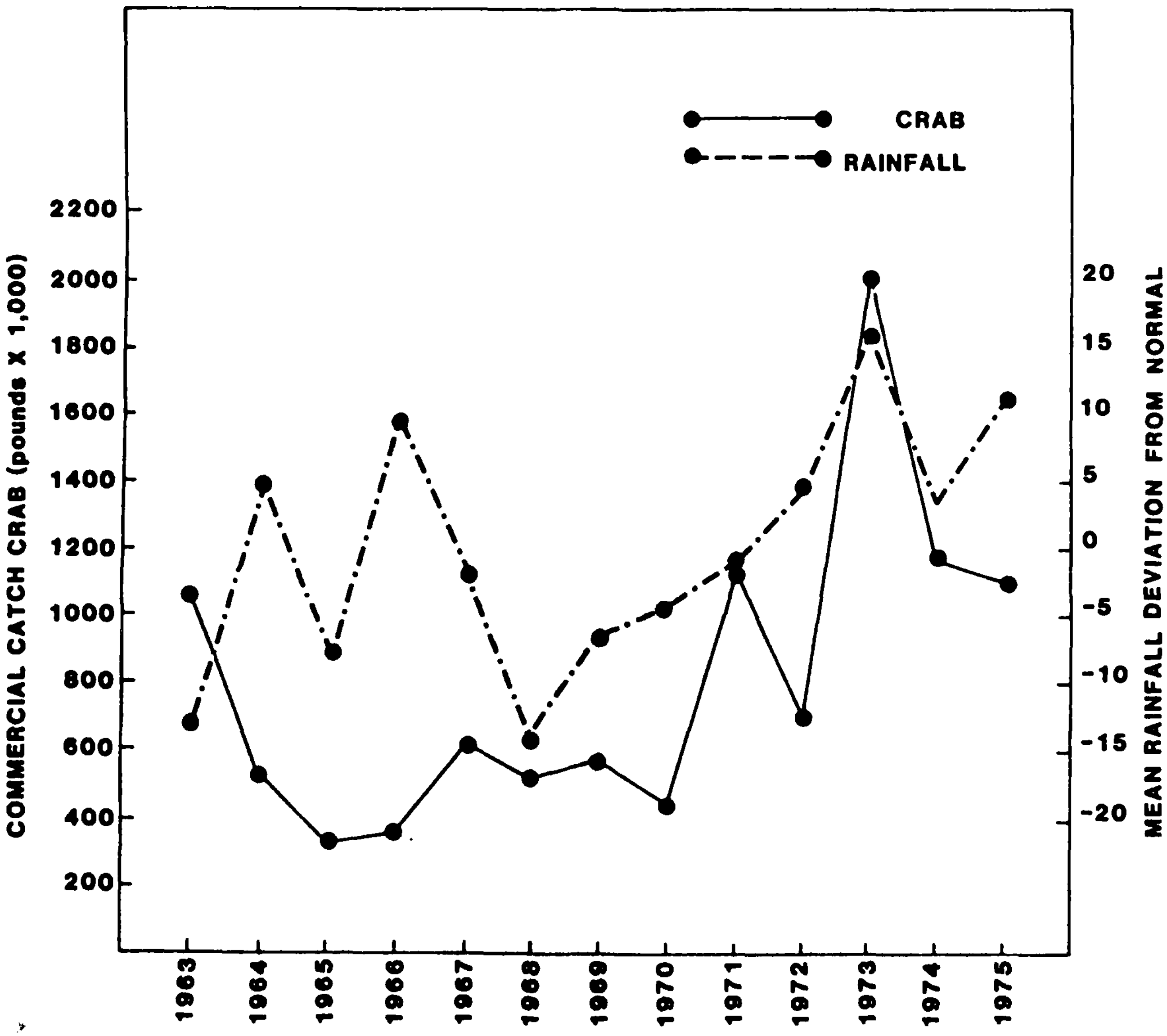


Figure 2. Comparison between commercial crab catch in Lake Pontchartrain, LA, and mean deviation of annual rainfall, 1963-1975.

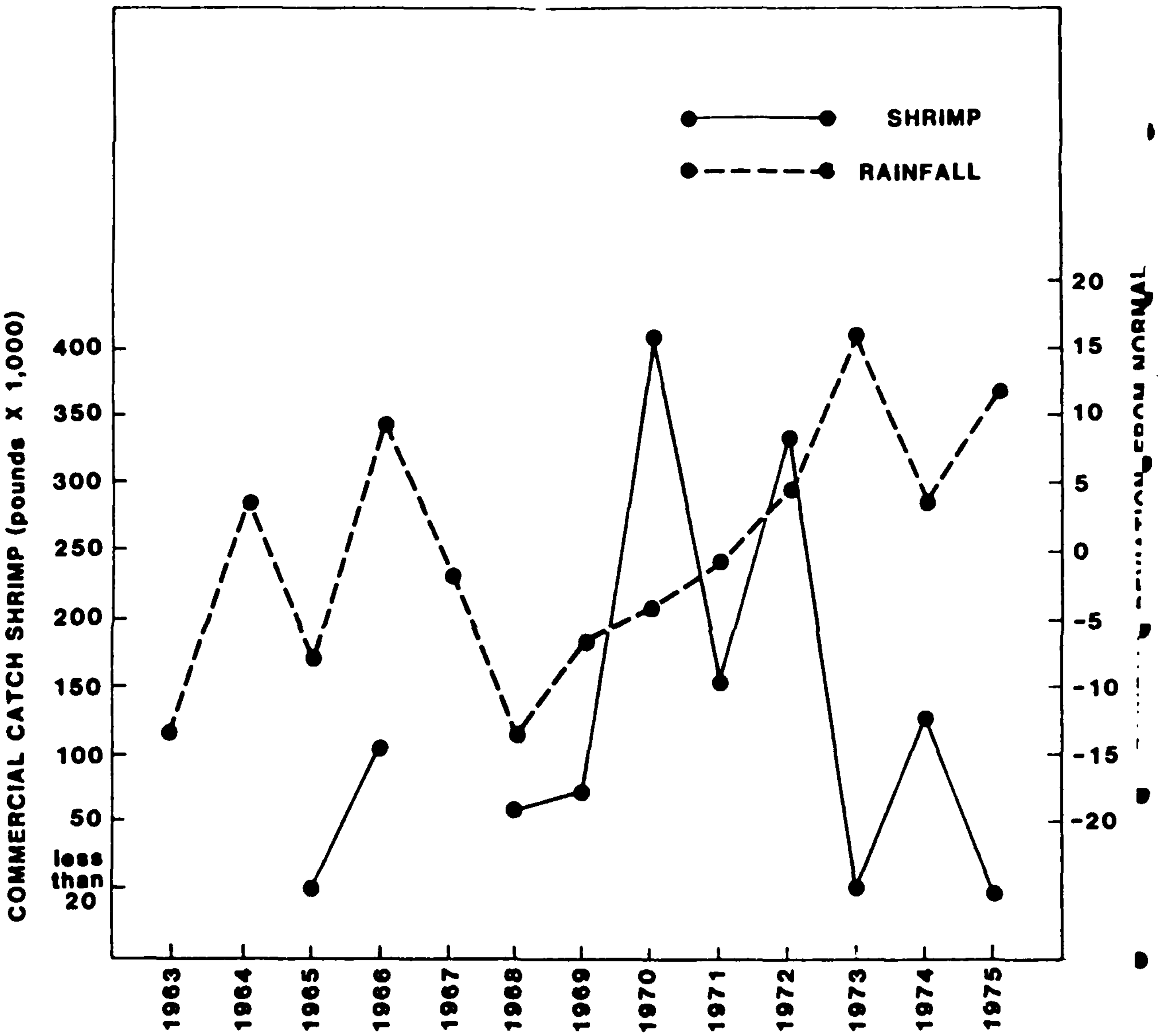


Figure 3. Comparison between commercial shrimp catch in Lake *Pontchartrain*, LA, and mean deviation of annual rainfall, 1963-1975.

Table 6. Salinity Data Recorded from This Study and from Previous Studies of Lake Pontchartrain, LA

Date	Salinity	Area	Reference
1953/54	1.2-12.2‰	Entire lake	Suttkus et al. (1954)
1967/69	1 - 10 ‰	Entire lake	Davis et al. (1970)
1968	0.0-7.4‰	Entire lake	Stern et al. (1968)
1968/69	0.2-5.9‰	New Orleans shore	Stern and Stern (1969)
1970/72	0.6-8.6‰	Entire lake	Tarver and Dugas (1973)
1973	0.2-2.4‰ (a)	New Orleans shore	Poirrier and Mulino (1975) and Poirrier et al. (1975)
1972/74	0.0-18.9‰	Entire lake	Tarver and Savoie (1976)
1975	0.3-2.8‰ (a)	New Orleans shore	Poirrier and Mulino (1977)
1978	0.0-8.5‰	Entire lake	Present study

(a) Bonnet Carre Floodway opened.

The commercial fish species of Lake Pontchartrain can be grouped as follows (see Thompson and Verret, Chapter 12):

I. Freshwater species

A. Strictly freshwater

Aplodinotus grunniens - freshwater drum
Ictiobus spp. - buffalo

B. Facultative invader of brackish water

1. Sporadic invader
Ictalurus punctatus - channel catfish
2. Frequent invader
Ictalurus furcatus - blue catfish
Lepisosteus spp. - gar

II. Euryhaline species. (Fishes with a wide range of tolerance to salinity)

A. Anadromous fishes. Entering freshwater to breed; some are residual in freshwater; can enter high salinity at times.
Dorosoma spp. - shad

B. Marine or brackish-water fishes that invade strictly fresh water.
Paralichthys lethostigma - southern flounder

C. Marine fishes. Facultative invaders of water of moderate to low salinity; not entering fresh water.
Archosargus probatocephalus - sheepshead
Arius felis (*Bagre marinus* also?) - seacatfish
Cynoscion arenarius - white seatrout
Cynoscion nebulosus - spotted seatrout
Menticirrhus spp. - king whiting and kingfish
Micropogonias undulatus - croaker
Pogonias cromis - black drum
Sciaenops ocellata - red drum

As Poirrier and Mulino (1975) noted, Mississippi River water has a relatively high concentration of calcium salts and may permit penetration of the euryhaline marine component into these fresher environments, although Mississippi River water presently enters Lake Pontchartrain only when the Bonnet Carre Floodway is open. The presence of calcium

salts has been postulated to be a crucial factor in the facilitation of freshwater invasion of marine organisms (Odum 1953, Remane and Schlieper 1971). Tagatz (1968) discussed the ability of certain marine fishes to enter oligohaline waters (less than 5$^{\circ}/_{oo}$) in St. Johns River, Florida. Salinity ranges presented for these species that comprise the Lake Pontchartrain commercial catch are:

Arius felis 10.2-25.8$^{\circ}/_{oo}$
Cynoscion nebulosus 0-11.1$^{\circ}/_{oo}$
Micropogonias undulatus 0-30.2$^{\circ}/_{oo}$
Pogonias cromis 0-24.5$^{\circ}/_{oo}$
Sciaenops ocellata 0-22.7$^{\circ}/_{oo}$
Archosargus probatocephalus 0-26.8$^{\circ}/_{oo}$
Paralichthys lethostigma 0-30.2$^{\circ}/_{oo}$

Freshwater catfish (*Ictalurus furcatus* and *I. punctatus*), important commercially, may be affected by fluctuations in lake salinity. As shown in the above salinity classification list, both species have a limited ability to live in brackish waters. Renfro (1960), Rounsefell, (1964), Kelly (1965), Norden (1966), Perry (1968), Dugas (1970), Perrett et al. (1971), Swingle (1971), and Tarver and Savoie (1976) have discussed the ranges of salinity that are normally tolerated by these two species. The channel catfish is more intolerant of salinity and could disappear completely from Lake Pontchartrain if the normal salinity were raised above 2 to 3$^{\circ}/_{oo}$ (Perry 1968). The blue catfish is much more tolerant of increases in salinity. This species has been shown to live in salinities equal to or greater than the normal upper maximum in Lake Pontchartrain. Overall, this species seems to occur in most abundance in salinities below 9 to 10$^{\circ}/_{oo}$; it seems, however, to prefer salinities below 5$^{\circ}/_{oo}$ (Perry 1968, Kelly 1965).

Possibly of greater impact on the commercial fish catch in Lake Pontchartrain would be the alteration of the salinity regime towards

more freshwater conditions by the restriction of the source of Gulf of Mexico water. Group II C (Euryhaline-Marine fishes) includes most of the commercial species in Lake Pontchartrain and they prefer meso- and metahaline (Gunter 1961a) waters. Darnell (1958) discussed the general salinity pattern in Lake Pontchartrain and noted the increase from west to east in the lake. The highest salinities are nearest the three passes, and some of the commercial fishing is concentrated in these areas.

The blue crab fishery would be more tolerant of salinity changes in Lake Pontchartrain. Adkins (1972) indicated that blue crabs can exist in a wide range (0.0-31.4°/₀₀) during various phases of their life cycle. The larger crabs (those of commercial size) prefer lower (less than 10/₀₀) salinities and thus migrate from more metahaline to the oligohaline waters of Lake Pontchartrain. Rounsefell (1964) also indicated that larger blue crabs were found in the lower salinity waters during the Mississippi River-Gulf Outlet (MRGO) study (see section on effects of MRGO construction on Lake Pontchartrain).

Rounsefell (1964) noted that there was little salinity preference in the Lake Borgne study area for both brown and white shrimp. Barrett and Gillespie (1973) discussed the influence of salinity on commercial shrimp production. They noted the complex problem involved in the wide salinity ranges given in different shrimp studies. Gunter (1961b) postulated that white shrimp have a greater tolerance for low salinities than brown shrimp. Parker (1970) found brown shrimp in Galveston Bay in salinities ranging from 0.9 to 30.8 °/₀₀. This is a much greater range than normally occurs in Lake Pontchartrain (see Table 6). Tarver (1964) and others have noted that the introduction of low salinity waters into

Lake Pontchartrain via the Bonnet Carre Floodway results in low shrimp populations in the lake (see section on Bonnet Carre Floodway).

C. Temperature

In most studies of fish, crabs, shrimp, and other estuarine organisms, the only figures presented are average monthly temperatures or ranges of individual species. In a series of Gulf Coast studies (Swingle 1971, Alabama; Christmas 1973, Mississippi; Perret et al. 1971, Louisiana; Tarver and Savoie 1976, Lakes Pontchartrain-Maurepas), much of the catch data was presented in a combined temperature-salinity chart that has permitted analysis of temperature effects over different salinity ranges.

Figures 4-6 show that there is no significant correlation between mean annual temperature deviation and the commercial catch in the Lake Pontchartrain complex (fish: r = -.35; crab: r = .35; shrimp: r = -.05; NS @ 95% level). This is probably due to the small area covered by the figures and the fact that portions of the life history of the commercial species occur outside the Lake Pontchartrain-Maurepas area. Figure 7 shows the close correlation between air temperature and Lake Pontchartrain water temperature, so it seems a safe assumption that warm or cold years will result in similar conditions in the lake.

The fish community of Lake Pontchartrain is very seasonal, and thus the movements of most of the commercial species are temperature related (Thompson and Verret, Chapter 12). Cold water species such as the freshwater catfishes (*Ictalurus*) and speckled trout (*Cynoscion nebulosus*) are most abundant between December and early March. Several other commercial species of fish enter the lake as water temperatures rise. *Arius felis* (sea catfish), *Cynoscion arenarius* (white trout), *Micropogonias undulatus* (croaker), and *Pogonias cromis* (black drum) are warm water species.

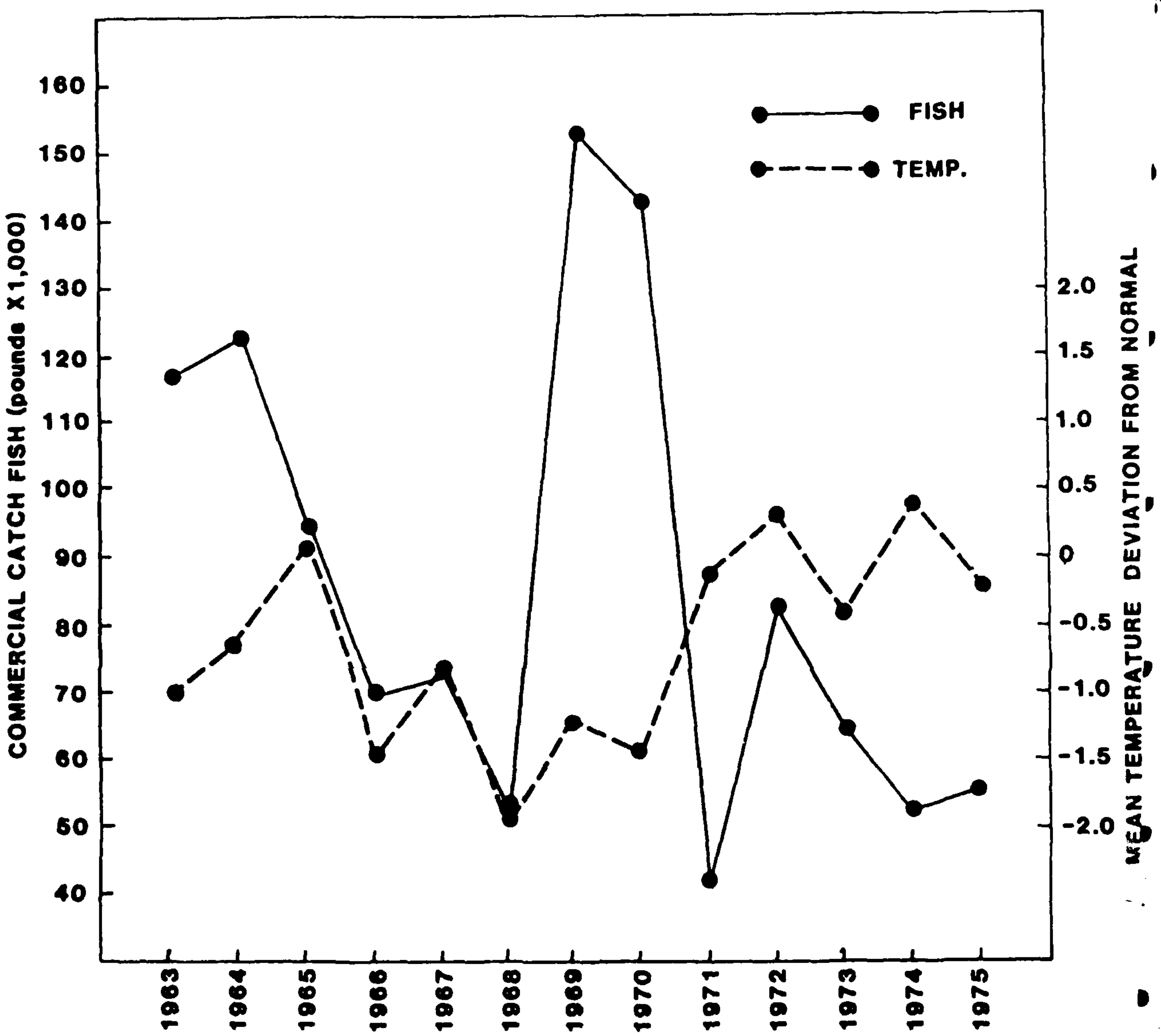


Figure 4. Comparison between commercial fish catch in Lake Pontchartrain, LA, and mean deviation of annual temperature, 1963-1975.

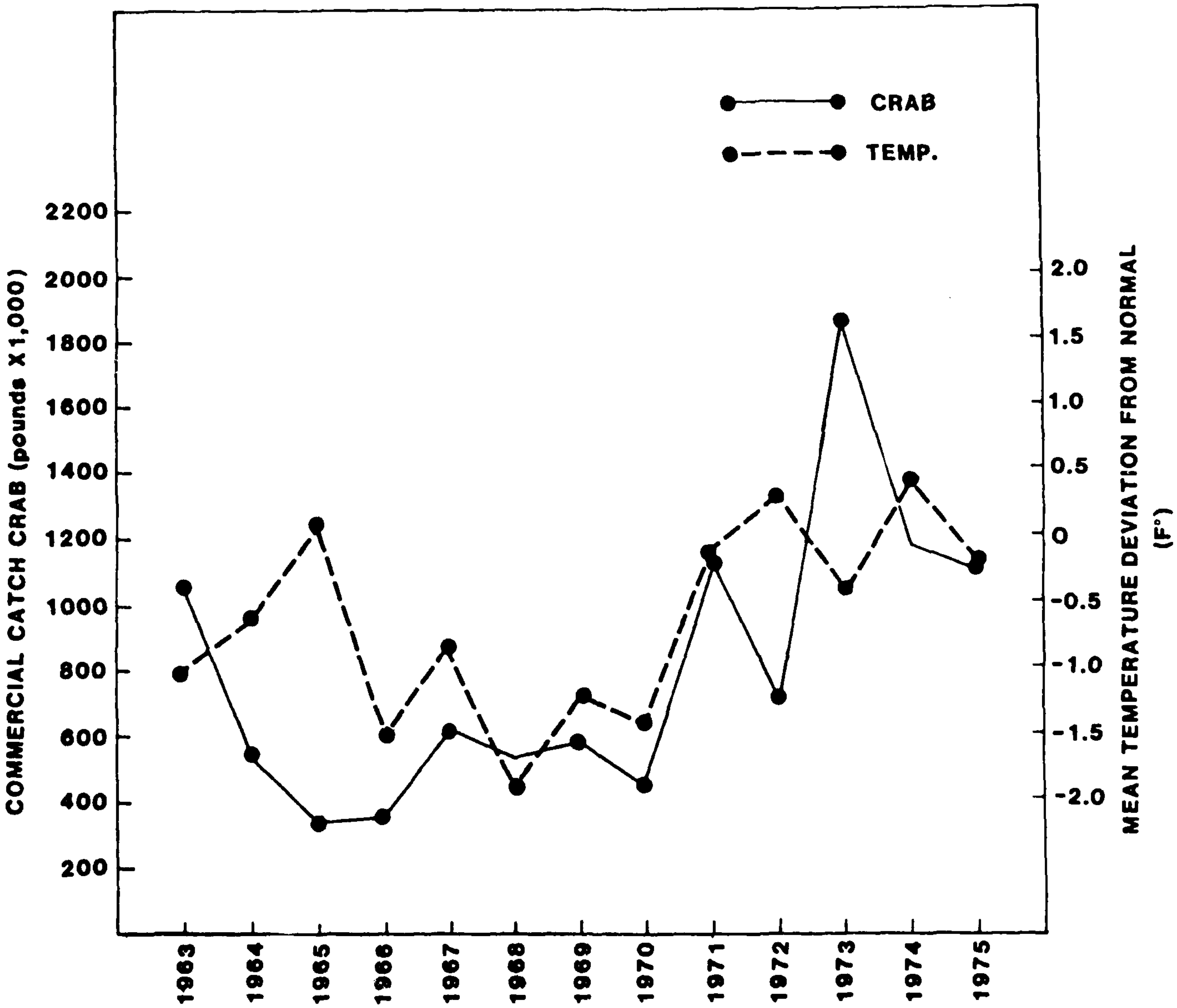


Figure 5. Comparison between commercial crab catch in Lake Pontchartrain, LA, and mean deviation of annual temperature, 1963-1975.

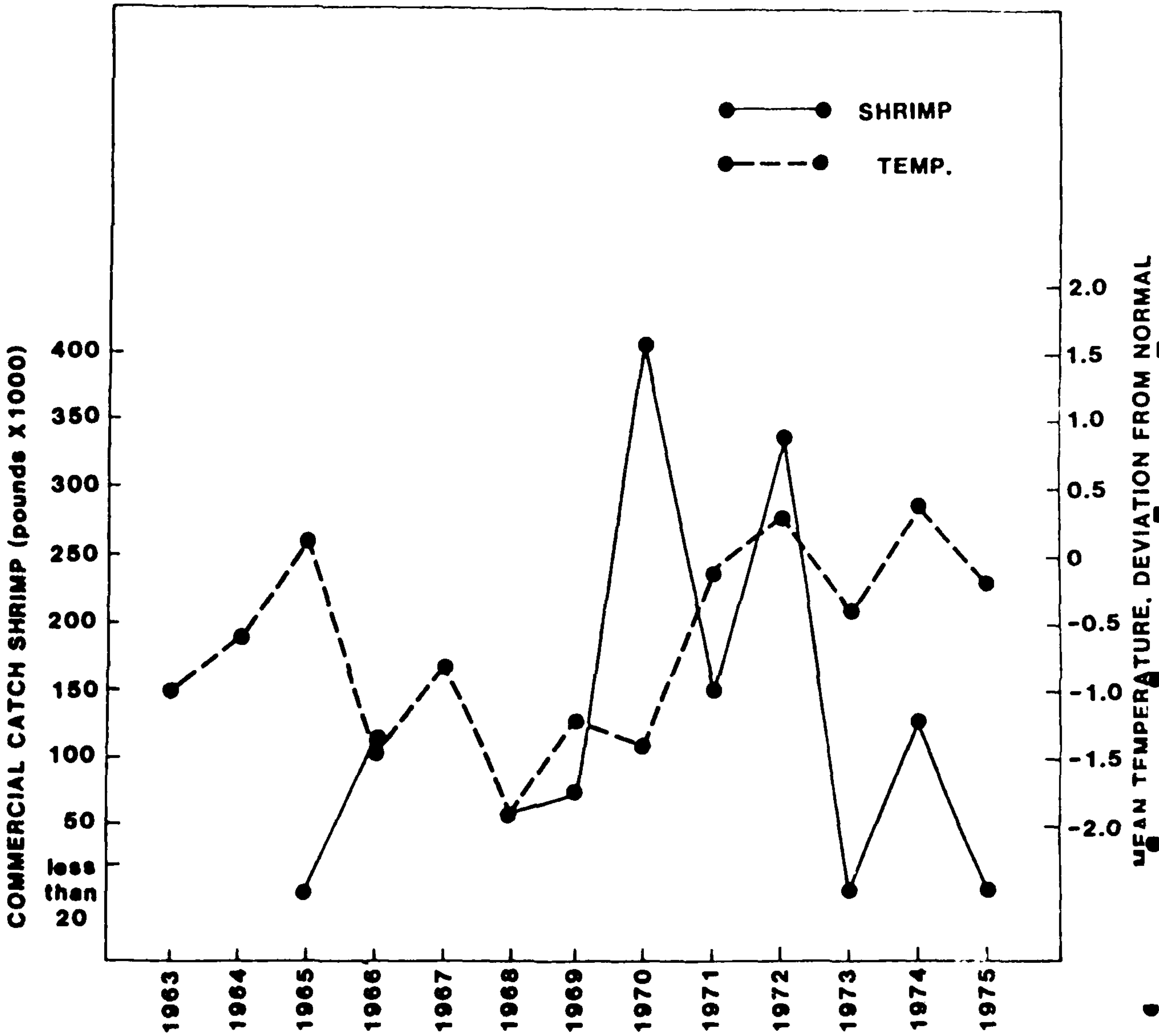


Figure 6. Comparison between commercial shrimp catch in Lake Pontchartrain, LA, and mean deviation of annual temperature, 1963-1975.

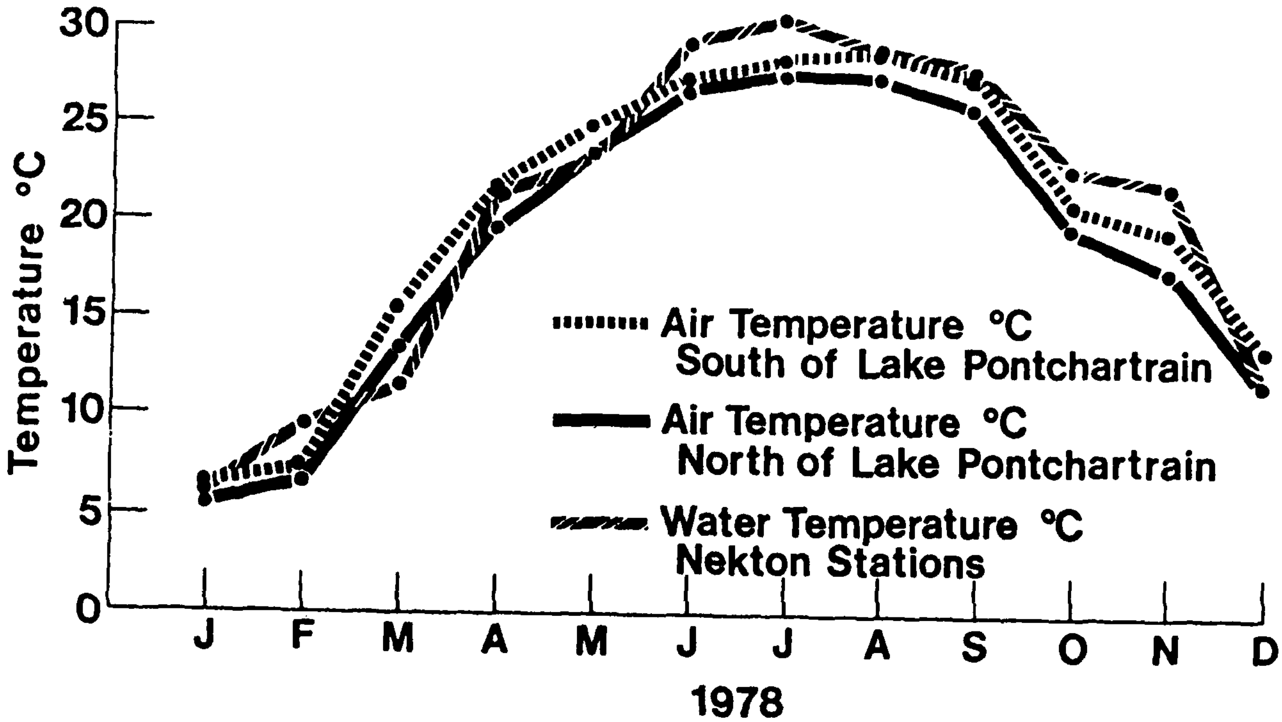


Figure 7. Comparison of monthly air temperatures north and south of Lake Pontchartrain, LA, with water temperatures for 1978.

Ford and St. Amant (1970), Gaidry and White (1973), and Barrett and Gillespie (1973) have stressed the importance of warming temperatures on shrimp production. Many of the major phases of the shrimp life cycle are temperature controlled. An increase in temperature would trigger the movement of brown shrimp postlarvae through the Chandeleur Sound-Lake Borgne area towards Lake Pontchartrain.

Adkins (1972) discussed the seasonality of the life history of the blue crab. He reported the lowest catch in the Lake Pontchartrain-Lake Borgne area (Hydroglogic Unit I) between October and February. With the onset of dropping temperatures, the blue crabs move towards offshore waters and return with the following year's increase in water temperature. Darnell (1959) found many of the younger crabs to inhabit the shallow, fresher areas during summer. Lake Pontchartrain may be critical as a nursery for these younger crabs that then leave and move towards deeper waters in the winter.

D. Turbidity

Turbidity is probably the most difficult of the lake parameters with which to establish good correlations. Tarver and Dugas (1973) discussed some aspects of the effects of turbidity in their study on dredging in Lake Pontchartrain. There seems to be a long-term (1953 to present) decrease in the clarity of Lake Pontchartrain. Suttkus et al. (1954) and Darnell (1958) reported visibility readings in the lake of 4-5 m (14 ft +) during summer periods. Our 1978 study showed maximum Secchi disc readings of less than one-half this value (i.e., 2 m). Although Lake Pontchartrain is naturally turbid (Darnell 1958 and 1962a), this decrease in clarity possibly has a deleterious effect on the commercial

catch. The only commercial group that is more turbidity tolerant than most species is the freshwater catfish (Ictalurus).

E. Substrate

Barnett and Gillespie (1973) reviewed the studies on bottom preferences in commercial shrimp. The mud bottom of Lake Pontchartrain seems well suited as the preferred bottom for both *Penaeus aztecus* and *P. setiferus* (William 1958). He reported that *P. aztecus* burrowed more extensively than did *P. setiferus*.

Overall substrate preference is not well known for many fishes, either commercial or non-commercial. Hoese and Moore (1977) noted that *Paralichthys lethostigma*, the commercial flounder species in Lake Pontchartrain and Lake Borgne, prefers a mud bottom.

Substrate preferences in the various stages in the life history of the blue crab are not documented.

F. Competition and Predation

Ecological interaction between competition and predation should be investigated as a part of any attempt to analyze commercial species. If the environment has been disturbed, the natural ecological balance could be altered, and a valuable commercial species may be shifted to an unfavorable competitive position.

Some of the potential competitive fish in Lake Pontchartrain can be grouped as follows:

1) bottom feeding mollusk eaters
2) piscivores
3) micro-predators (feeding on mysids, etc.)

Natural predator-prey patterns can be altered through this competitive imbalance and cannibalism can result (Zein-Eldin 1963). Darnell (1958) made a detailed study of the food of the major species in Lake Pontchartrain. Although a detailed analysis of the potential niche overlap was lacking, several points can be noted. Predation on the blue crab in Lake Pontchartrain is very intense and may affect the population levels in the lake. There seems to be competitive displacement between *Ictalurus furcatus* and *I. punctatus* and *Cynoscion nebulosus* and *C. arenarius* to reduce food overlap in these commercially successful and important species.

II. Man-Induced Factors

A. Mississippi River-Gulf Outlet (MRGO)

Rounsefell (1964) reported on a preconstruction study of the area traversed by the MRGO and discussed some potential environmental changes caused by the direct access of high salinity Gulf of Mexico water northward into the Lake Borgne-Lake Pontchartrain area.

Fontenot and Rogillio (1970) listed 10 species of fishes that have limited ability to adapt to higher salinities and have apparently disappeared in their Lake Borgne study area because of saltwater intrusion from the MRGO. Rogillio (1975) also noted increases caused by the MRGO in some of the Lake Borgne study areas.

Rounsefell (1964) attempted to set up a salinity classification for the fish in the MRGO area by showing the potential change in the fish fauna should a dramatic increase in salinity occur. He discussed the potential changes in the estuarine system and hypothesized salinity increases between 4-6°/₀₀ in Lake Pontchartrain. If such changes were to take place, they potentially would greatly alter the fish fauna in

the lake. Table 6 presents salinity information from known studies of Lake Pontchartrain between 1953 and 1978, and no dramatic shift in salinity is apparent. Darnell (1958, 1962a) reported a normal salinity range in Lake Pontchartrain of 3-8°/oo, with an average of about 5-6°/oo. Tarver and Dugas (1973) listed a range of 0.6-8.6°/oo, with a calculated average (Poirrier and Mulino 1977) of 4.2°/oo. Tarver and Savoie (1976) gave a range of 0.0-18.6°/oo, averaging 1.7°/oo. The present study during 1978 found a range of 0.0-8.5°/oo. The minimum average for the year was 0.9°/oo and the maximum average was 4.2°/oo. The yearly average for the lake was 2.6°/oo. The conclusion drawn from these data is that the MRGO-IHNC has, to date, apparently not greatly shifted the salinity regime of Lake Pontchartrain in an upward direction. Thus, it probably has not had a great effect on the commercial catch of Lake Pontchartrain. It might be beneficial in permitting seasonally migrating species such as croaker, seatrout, blue crab, and shrimp greater access to the lake. Basically, it provides a "third tidal pass" for their movements. Additional detailed study is needed to evaluate this hypothesis.

A comparison of three major studies on the fish community of Lake Pontchartrain (Suttkus et al. 1954, Tarver and Savoie 1976, Thompson and Verret, Chapter 12) indicates no significant changes towards either a more freshwater or more marine fauna. The community probably changes slightly with the yearly variations of salinity (and other factors) and the catches reflect these variations. Certain marine species, i.e., *Cynoscion arenarius*, were more abundant in the 1954 study (as compared to 1978), yet they are not listed in the harvest data before 1969.

B. Bonnet Carre Floodway

The Bonnet Carre Spillway Floodway is a flood structure that diverts Mississippi River water into the Gulf of Mexico via the Lake Pontchartrain-Lake Borgne estuary complex. When in operation, this structure has a profound effect on the hydrology and biology of Lake Pontchartrain and surrounding areas. To date the floodway has been opened as follows:

1937	-	39 days
1945	-	55 days
1950	-	36 days
1973	-	75 days
1975	-	12 days
1979	-	39 days

Viosca (1938), Gowanloch (1950), Butler and Engle (1950), Owen and Walters (1950), Gunter (1953), Darnell (1962a), Tarver (1974), and Poirrier and Mulino (1975, 1977) have reviewed the effects of the floodway on different aspects of the entire southeast Louisiana estuarine system. To summarize many of these studies, the opening of the floodway replaces the normal oligohaline Lake Pontchartrain water with fresh, cold, highly silt-laden Mississippi River water (cf. Chapter 4).

Tarver (1974) discussed the effects of the long opening of 1973 on the commercial fishing industry in Lake Pontchartrain. He believes that changes in salinity and increased silt load are the major alterations that affect the commercial biota. Some of the loss in fisheries in Lake Pontchartrain seem to be compensated for by increased catches in Lake Borgne of those species that can avoid the spillway waters, but Rogillio (1975) noted the influence of the 1973 opening in the study area near the MRGO/Lake Borgne area (Hopedale Lagoon). He plotted a water flow map showing the areas of influence in the entire Lake Pontchartrain-Lake Borgne estuary.

Shrimp production in Lake Pontchartrain in 1973 and 1975 was among the lowest recorded (see Table 2). Crab catches were very high and may reflect a good harvest prior to the opening of the floodway. The 1973 fish catches show a very high freshwater catfish harvest, as noted by Tarver (1974). In 1975, freshwater catfish and shad harvests both showed possible positive effects of the floodway opening on the freshwater biota.

To arbitrarily denounce the opening as catastrophic would be misleading despite protests by commercial and sports fishermen (Marshall 1979). As Gunter (1952), Darnell (1962a), and Tarver (1974) noted, this process is similar to the natural Mississippi River flooding and is beneficial in adding nutrients to the lake. The short-term effect on the estuarine complex may be detrimental, but it could be beneficial over a more long-range cycle. Tarver and Dugas (1973) suggest that a controlled series of openings of the Bonnet Carre Floodway should be investigated as a management technique for increasing the spawning of the clam _Rangia cuneata_ to increase the supply of dredge shell.

Viosca (1927) discussed the beneficial aspects of the natural cycle of flooding in the lower Mississippi Valley as a means of rejuvenating nutrients for the commercial fishery.

C. Dredging

Commercial dredging for _Rangia cuneata_ has been going on in the Lake Pontchartrain-Maurepas complex since the early 1930's. As reported by Tarver and Dugas (1973), little research has been done on the environmental impact of this shell dredging. They report on research in Lake Pontchartrain conducted to assess potential changes due to shell dredging.

The impact on the commercial fishery would probably result from an interplay of the following alterations:

1) increase in turbidity
2) alteration of water chemistry
3) interruption of critical food chains
4) physical damage
5) behavioral aberration
6) increased turnover of nutrients and toxins

These factors are potentially detrimental to the commercial fishery. Several of these factors could dramatically reduce commercial stocks to the point of economic destruction. Thomas (1979) reports that destruction of crab traps by the dredging operations in Lake Pontchartrain caused an economic hardship on the crab fishermen. Ideally the dredging operations should be coordinated with the seasonality of the commercial operations to reduce the potential adverse interreactions.

D. Shoreline Alteration

Montz (1978) recorded a shoreline for Lake Pontchartrain of 191.5 km (119 miles). Roughly 63 km (33%) of this has been altered at the present time through the construction of seawalls, levees, or land-alteration projects. Along the south shore of Lake Pontchartrain, from South Point-Point aux Herbes to the Jefferson-St. Charles Parish line, roughly 47.5 km of shoreline has been permanently altered with the construction of levees and concrete seawalls. Saucier (1963, Fig. 7) reported that the alterations in this area have gone on for so long that "natural shoreline types are not definitely known."

Saucier (1963) compared changes in the Lake Pontchartrain marsh areas between the 1930's and the 1950's. He found increased open water and attributed this to several factors including:

1) increased and uncontrolled burning
2) invasion of brackish water
3) contamination/poisoning of plants by man
4) subsidence

Saucier concluded that these factors are contributing to an unstable shoreline and leading to a rapid shoreline retreat. Perret et al. (1971) listed one area near the north shore of Lake Pontchartrain west of the mouth of The Rigolets that had been filled. He discussed the effects of these areas on the estuarine environment. Also these data included a large area (approximately 12 square miles) of the New Orleans East marsh that had been leveed and drained (primarily for real estate). Areas not included by Perrett et al. (1971) that have been recently altered include:

1) Eden Isle (housing development), north shore of Lake Pontchartrain just east of Big Point.

2) Venetian Isle (housing development), Chef Menteur Pass marsh near mouth of Bayou Savrage.

Chabreck et al. (1968) presented a vegetation-type map for coastal Louisiana and showed three types of marsh around Lake Pontchartrain:

1) Fresh Marsh - This is located on either side of the Tchefuncte River and in the St. Charles Parish area bordering the south shore of the lake.

2) Intermediate Marsh - This is located along the south shore in the St. Charles Marsh area and slightly inland along the north shore from Green Point eastward.

3) Brackish Marsh - This is the most extensive marsh type in the Lake Pontchartrain area covering the shoreline from Green Point on the north shore eastward around the lake to the South Point area. This marsh form covers most of the shore area in the eastern part of the Lake Pontchartrain/Lake St. Catherine/Lake Borgne estuary.

Chabreck and Linscombe (1978) showed more extensive fresh and intermediate marsh on the west side of the lake and a change from fresh

and intermediate to brackish and intermediate marsh in St. Charles Parish on the southwest corner of the lake. The overall extent of this apparent change in vegetation and its effect on the fish community is not known at present.

Turner (1977) discussed a relationship between intertidal area and shrimp production. Lindall and Soloman (1977) discussed the threat to fishery resources of the Gulf of Mexico posed by the continuing destruction and alteration of aquatic and estuarine habits. Continued shoreline alteration and wetland destruction will therefore most likely prove deleterious to all commercial production in Lake Pontchartrain. Possibly more important than the wetlands surrounding Lake Pontchartrain would be that area seaward in Lake Borgne-Chandeleur Sound. Since most of the commercial species populations are migrants to Lake Pontchartrain, conditions for the early life history stages outside may be crucial. Chabreck et al. (1968) showed that the Lake Borgne marsh-type changes from brackish to salt marsh in the outer eastern region. This area is essential to the early development of the young of many of the commercial species.

E. Loss of Grassbeds

Perrett et al. (1971) and Montz (1978) presented information on the extensive submerged grassbeds, most of which are confined to the north shore of Lake Pontchartrain. The grassbeds are important to the commercial catch of Lake Pontchartrain because they serve as a major nursery area of many species, including *Cynoscion nebulosus*, *Callinectes sapidus*, and *Penaeus aztecus*, three of the most important commercial species in Lake Pontchartrain. Population stability of the species would be greatly

reduced if these grassbeds were to undergo any major reduction in area. Destruction of these beds would be detrimental to many of the commercial species in the lake. Perrett et al. (1971) presented a total estimate of 20,000 acres; Montz (1978) listed roughly 2,000 acres in the lake. There appears to be no major environmental degradation of the area to explain such a major discrepancy, and the most logical answer lies in a difference in sampling technique. Montz (1978) outlined his sampling procedure in great detail, and his figure is probably the more accurate of the two studies (J. Tarver, pers. comm.). During the present study (Thompson and Verret, Chapter 12), the north shore grassbeds appeared to be healthy and vigorous and contained a highly diversified fish fauna. Turner, Darnell, and Bond (Chapter 10) outlined the recent history on distribution and abundance of submerged macrophytes in the lake and concluded that between 1954 and 1973 (see Montz 1978), "The abundance and distribution of the grasses *Ruppia* and *Vallisneria* in Lake Pontchartrain have declined whereas other rooted aquatics have expanded their range in certain areas." They also reviewed potential causes for this decline but made no hypotheses on reasons for any increases.

F. Population Growth and City Effects

Perret et al. (1971) listed the following municipalities as being involved in discharging storm water and partially treated sewage (and possibly some untreated sewage as a result of infiltration and illegal connections) into Lake Pontchartrain:

1) Slidell (via Bayou Bonfouca)
2) Mandeville
3) East Bank of Jefferson Parish (via Bonnabel, Elmwood, and Soniat Canals)

They also listed the following industries as those that discharge industrial wastes into Lake Pontchartrain:

1) Air Products and Chemical Co. (via Intracoastal Waterway)

2) Airco. Industrial Gases (via New Orleans Ship Channel)

3) Shell Processing Plant (via MRGO)

Although none of the industries bordering the Inner Harbor Navigation Canal (IHNC) were listed, it seems likely that these industries are adding to the influx of industrial wastes to Lake Pontchartrain via this canal.

Poirrier et al. (1975) noted the relationship between Lake Pontchartrain water quality and its epifaunal invertebrates and concluded (Poirrier and Mulino 1977) that "Lake Pontchartrain is undergoing environmental change due to the construction of a navigation canal [possibly referring to the MRGO], which has changed its salinity regime, and the expansion of the New Orleans Metroplex, which has reduced water quality by discharging sewage and storm-water runoff into the lake."

Table 7 presents population growth figures for four parishes surrounding Lake Pontchartrain that are showing the greatest growth rate and would most likely be included in Poirrier's definition of the "New Orleans Metroplex." The 1975 Jefferson-Orleans Parish area had a population of 958,786 and at the present time, may be over one million. Even in the less populous St. Bernard-St. Tammany area, the population nearly doubled between 1960 and 1975. Craig and Day (1977) discussed the dangers of wetland destruction and increased eutrophication that could occur in Lake Pontchartrain as a result of the population increase. Using a phosphorus loading model, they theorized that Lake Pontchartrain could

Table 7. Population Statistics for 4 Major Parishes Bordering Lake Pontchartrain

Parish	1960[1]	1970	1975	Change 1960 to 1975 (%)
Jefferson-Orleans	836,294	931,700	958,786	122,492 (14.6%)
St. Bernard-St. Tammany	70,829	114,770	135,637	64,808 (91.5%)
Total (4 parish)	907,123	1,046,470	1,094,423	187,300 (20.6%)

[1] U.S. Census of Population; 1960, 1975.

undergo great eutrophication and that this increased level ... "will within 30 years, destroy most of the desirable aesthetic, recreational, and commercial values of Lake Pontchartrain." Obviously, if this model proves to be an accurate assessment, commercial fishing in Lake Pontchartrain could collapse.

G. Petroleum Industry Activities

At the present time there are a considerable number of natural gas wells in Lake Pontchartrain. St. Amant (1971, 1972a) discussed many of the potential adverse effects of the activities of the petroleum industry, particularly in the inshore coastal areas. He listed five factors that could greatly affect the commercial industry in Lake Pontchartrain and wetlands in general:

1) Dredging and channelization for navigation of equipment
2) Pipeline construction resulting in wide areas of disrupted marshland
3) Shoreline alteration (see Figures 3 and 4 in St. Amant [1972a] for dramatic evidence of this problem)
4) Long-term secondary effects from upsetting natural ecological balances
5) Chronic pollution from such parameters as oil, bleed water, and drilling mud

With the potential for increased petroleum industry activities over widespread areas, expansion of the operations in Lake Pontchartrain should be carefully evaluated to prevent destruction of any other of the lake's resources.

III. Economic Factors

In any discussion of factors that influence the commercial catch from the Lake Pontchartrain-Maurepas area, economic or economically

controlled factors must be considered. Table 8 shows that the complex is not very productive on a volume and area basis. Table 9 shows that shrimp production in Lake Pontchartrain contributes very little ($\bar{X}$ = 0.41%) to the inshore catch of brown and white shrimp in Louisiana. St. Amant (1972b) reported 35.6 lbs/acre for Louisiana shrimp production compared with 0.28 lbs/acre for Lake Pontchartrain (Table 8).

A similar listing of the hard blue crab catch for an approximate 10-year period from 1961 to 1971 shows that Lake Pontchartrain contributed (on an average) 6.4% of the total Louisiana catch (Adkins 1972; Yearly Reports, NMFS). The lake basin contributes roughly 13% of the state area fished for blue crabs (Barrett 1970). Louisiana produces on an average 4.1 lbs/acre (St. Amant 1972b), whereas Lake Pontchartrain's harvest is 1.8 lbs/acre (Table 8).

Table 10 lists the commercial catch of fish, crab, and shrimp from Louisiana between 1963 and 1978 and compares the Lake Pontchartrain catch to the state total on a weight and value basis. The commercial fish catch of the lake contributes less than 0.01% (by weight) and 0.10% (by value) to the total state catch. Relative to the Louisiana fish catch, the Lake Pontchartrain catch has declined to an insignificant contribution, as shown on Table 11 for 1963-1975. The Lake Pontchartrain catch was less than the catch of Lake Borgne for 11 of these 13 years and averaged only 42% (by weight) and 32% (by value) in comparison. The commercial catch from Lake Borgne for this same period is shown in Table 12. Starting in 1976, the NMFS combined these two areas into a single block of catch data. Table 13 shows the commercial catch from the Lake Pontchartrain-Lake Borgne area. The combined catch from both lakes

Table 8. Commercial Catches on the Basis of the Area and Volume[1] of Lakes Pontchartrain and Maurepas, 1963-1975 [2, 3]

		Lbs/acre	Lbs/acre-ft.	$/acre	$/acre-ft.
	Fish	.26	.02	.05	.004
1963	Crab	2.29	.21	.24	.022
	Shrimp	-	--	---	---
	Fish	.27	.02	.06	.005
1964	Crab	1.22	.11	.16	.014
	Shrimp	--	---	---	---
	Fish	.21	.02	.05	.005
1965	Crab	.71	.06	.10	.009
	Shrimp	.01	*	*	*
	Fish	.15	.01	.03	.003
1966	Crab	.78	.07	.09	.008
	Shrimp	.24	.02	.11	.010
	Fish	.16	.01	.03	.003
1967	Crab	1.33	.12	.13	.011
	Shrimp	---	---	---	---
	Fish	.11	.01	.03	.002
1968	Crab	1.13	.10	.15	.014
	Shrimp	.13	.01	.08	.007
	Fish	.34	.03	.06	.005
1969	Crab	1.27	.11	.19	.017
	Shrimp	.16	.01	.08	.007
Total	Fish	1.50	.13	.31	.028
1963-	Crab	8.73	.78	1.06	.095
69	Shrimp	.54	.05	.28	.025
	Fish	.31	.03	.05	.005
1970	Crab	.99	.09	.11	.010
	Shrimp	.90	.08	.20	.018
	Fish	.09	.01	.02	.002
1971	Crab	2.46	.22	.40	.036
	Shrimp	.34	.03	.08	.007
	Fish	.18	.02	.05	.004
1972	Crab	1.56	.14	.29	.026
	Shrimp	.74	.07	.30	.027
	Fish	.14	.01	.05	.004
1973	Crab	4.44	.40	.79	.071
	Shrimp	.02	*	.02	.002
	Fish	.12	.01	.03	.002
1974	Crab	2.57	.23	.54	.048
	Shrimp	.28	.03	.09	.008
	Fish	.12	.01	.02	.002
1975	Crab	2.23	.20	.49	.044
	Shrimp	.01	*	.02	.002
Total	Fish	.96	.09	.22	.020
1970-	Crab	14.25	1.28	2.61	.234
75	Shrimp	2.29	.20	.72	.065
Total	Fish	2.46	.22	.54	.048
1963-	Crab	22.98	2.06	3.68	.329
75	Shrimp	2.83	.25	1.00	.089
	Fish	.21	.02	.04	.004
X̄ 1963-	Crab	1.24	.11	.15	.014
69	Shrimp	.14	.01	.07	.006
	Fish	.16	.02	.04	.003
X̄ 1970-	Crab	2.38	.21	.44	.039
75	Shrimp	.38	.03	.12	.011
	Fish	.19	.02	.04	.004
X̄ 1963-	Crab	1.77	.16	.28	.025
75	Shrimp	.28	.03	.10	.009

[1] Lake Pontchartrain-Maurepas area = 456,318 acres; volume = 5,098,490 acre-ft. (Barrett 1970)

[2] Catch data from National Marine Fisheries Service, New Orleans office.

[3] Shrimp data missing for 1963, 1964, and 1967.

*Dollar values less than $.01/acre or lbs. less than .001/acre ft.

Table 9. Comparison of Lakes Pontchartrain/Maurepas commercial shrimp catch[1] with Louisiana total inshore catch, 1963-1972[2]

Year	Pounds Pont./Maur.	Pounds Inshore	Pont.-Maur./Inshore
1963	---	40,434,845	---
1964	---	23,505,408	---
1965	5,000	27,372,215	.0002
1966	107,900	27,206,738	.0040
1967	---	35,117,790	---
1968	60,000	36,316,453	.0017
1969	73,600	43,083,911	.0017
1970	409,000	44,573,201	.0092
1971	154,600	47,406,401	.0033
1972	335,800	38,351,009	.0088
$\bar{X}$	163,700	36,336,797	.0041

[1]Data taken from National Marine Fisheries Service, New Orleans Office.

[2]Data modified from Barrett and Gillespie (1973), Table 5.

. .. 10. Total Commercial Catches of Fish, Crab, and Shrimp from Louisiana, 1963-1978[1]

		Pounds x 1000 (% catch)		$ value x 1000 (% catch)		Lake Pontchartrain % Pounds - $ value
1963	Fish	650,672	(88.0)	9,679	(32.2)	.02 - .22
	Crab	8,311	(1.1)	611	(2.0)	12.58 - 18.18
	Shrimp	80,809	(10.9)	19,789	(65.8)	--- ---
1964	Fish	618,080	(90.4)	11,033	(36.3)	.02 - .25
	Crab	5,892	(0.9)	506	(1.7)	9.43 - 14.19
	Shrimp	59,382	(8.7)	18,794	(62.0)	--- ---
1965	Fish	704,845	(90.7)	13,817	(40.4)	.01 - .18
	Crab	9,488	(1.2)	776	(2.3)	3.43 - 6.08
	Shrimp	62,593	(8.1)	19,584	(57.3)	* - .01
1966	Fish	580,315	(89.2)	11,581	(31.6)	.01 - .14
	Crab	8,114	(1.2)	622	(1.7)	4.40 - 6.62
	Shrimp	62,269	(9.6)	24,388	(66.7)	.17 - .21
1967	Fish	547,255	(86.8)	8,357	(24.9)	.01 - .19
	Crab	7,605	(1.2)	641	(1.9)	7.97 - 9.10
	Shrimp	75,317	(12.0)	24,573	(73.2)	--- ---
1968	Fish	661,752	(89.5)	9,815	(26.9)	* - .12
	Crab	9,835	(1.3)	1,014	(2.8)	5.25 - 6.80
	Shrimp	67,768	(9.2)	25,623	(70.3)	.09 - .15
1969	Fish	901,582	(90.5)	15,969	(31.6)	.02 - .16
	Crab	11,799	(1.2)	1,233	(2.4)	4.89 - 7.02
	Shrimp	82,881	(8.3)	33,356	(66.0)	.09 - .11
1970	Fish	1,002,083	(90.8)	22,250	(38.5)	.01 - .11
	Crab	10,344	(0.9)	1,008	(1.7)	4.37 - 4.94
	Shrimp	90,939	(8.3)	34,612	(59.8)	.45 - .27

[1]Data taken from Louisiana Landing Annual Summary (1963-1978) and Fishery Statistics of the United States (1963-1968). National Marine Fishery Service and Bureau of Commercial Fisheries.

Table 10. (Continued)

Year		Pounds x 1000	(% catch)	$ value x 1000	(% catch)	Lake Pontchartrain % Pounds - $ value
	Fish	1,254,994	(92.3)	22,654	(33.6)	* .04
1971	Crab	12,313	(0.9)	1,382	(2.1)	9.01 - 13.25
	Shrimp	92,475	(6.8)	43,284	(64.3)	.17 - .09
	Fish	968,152	(90.8)	18,536	(27.5)	* - .12
1972	Crab	15,185	(1.4)	1,886	(2.8)	4.68 - 7.00
	Shrimp	82,988	(7.8)	47,021	(69.7)	.40 - .29
	Fish	939,490	(92.0)	41,772	(46.8)	* - .05
1973	Crab	23,199	(2.3)	2,943	(3.3)	8.74 - 12.21
	Shrimp	58,648	(5.7)	44,511	(49.9)	.02 - .02
	Fish	1,135,822	(93.4)	44,346	(55.9)	* - .03
1974	Crab	20,735	(1.7)	2,828	(3.6)	5.66 - 8.66
	Shrimp	59,581	(4.9)	32,202	(40.5)	.22 - .13
	Fish	1,032,803	(93.6)	34,789	(44.4)	* - .03
1975	Crab	17,255	(1.6)	2,665	(3.4)	5.90 - 8.36
	Shrimp	53,134	(4.8)	40,968	(52.2)	.01 - .02
	Fish	1,114,570	(91.9)	43,945	(34.7)	
1976	Crab	15,299	(1.3)	3,206	(2.5)	**
	Shrimp	82,356	(6.8)	79,688	(62.8)	
	Fish	787,035	(86.7)	35,521	(28.0)	
1977	Crab	16,379	(1.8)	4,335	(3.4)	**
	Shrimp	104,018	(11.5)	87,213	(68.6)	
	Fish	1,530,610	(92.8)	70,764	(40.4)	
1978	Crab	14,904	(.9)	3,387	(1.9)	**
	Shrimp	104,385	(6.3)	100,848	(57.7)	

** Lake Pontchartrain data combined with Lake Borgne, no comparison made.

Table 11. Comparison of Total Commercial Catches of Lake Pontchartrain and Lake Borgne, 1963-1975[1]

	Lake Pontchartrain			Lake Borgne	
	Pounds (x 1000)	$ value	%[2]	Pounds (x 1000)	$ value
1963	1,166	133,585	41,25	2,819	524,392
1964	679	99,203	28,21	2,385	479,552
1965	425	74,075	22,28	1,928	260,011
1966	535	108,078	31,46	1,754	233,561
1967	679	73,979	25,13	2,716	564,921
1968	628	117,896	15,11	4,149	1,103,332
1969	805	148,422	19,14	4,244	1,095,435
1970	1,002	165,806	31,22	3,258	744,718
1971	1,317	229,968	86,49	1,528	473,278
1972	1,130	272,678	51,41	2,200	661,539
1973	2,103	392,218	134,75	1,573	525,023
1974	1,356	299,429	175,114	773	262,489
1975	1,079	242,692	90,49	1,199	495,723
TOTAL	12,904	2,358,029	42,32	30,526	7,423,974
MIN	425	73,979	15,11	773	233,561
MAX	2,103	392,218	175,114	4,244	1,103,332
$\bar{X}$	993	181,387	58,39	2,348	571,075

[1] Data from National Marine Fisheries Service, New Orleans Office.

[2] Lake Pontchartrain catch expressed as percentage of Lake Borgne catch by pounds and dollar value; figure over 100% indicates greater Lake Pontchartrain catch, i.e., 41,25 shows that the Lake Pontchartrain poundage was 41% of Lake Borgne and the value was 25%.

Table 12. Commercial Catches of Fish and Invertebrates from Lake Borgne, 1963-1975[1]

	1963		1964	
	Pounds	$ value	Pounds	$ value
Fish				
Black Drum	21,300	1,704	19,300	1,544
Black Mullet	1,700	68	1,400	70
Croaker	500	25	2,000	100
Flounder	2,600	447	3,100	516
Gar	5,100	255	---	---
King Whiting	6,800	340	9,000	587
Red Drum	30,000	6,000	14,100	2,538
Sawfish	---	---	---	---
Seacatfish	700	35	500	50
Seatrout, Spotted	25,900	6,475	10,700	2,675
Seatrout, White	4,200	210	1,900	113
Sheepshead	14,600	1,168	7,300	584
Spot	3,300	165	800	40
Tripletail	---	---	---	---
Total Fish	116,700	16,892	70,100	8,817
Invertebrates				
Blue Crab (Hard)	1,142,500	78,912	1,095,400	71,200
Blue Crab (Soft)	8,100	4,050	6,000	3,600
Shrimp (Heads On)	1,037,500	248,127	841,200	251,030
Oysters, Publ, Spring	---	---	---	---
Oysters, Publ, Fall	---	---	---	---
Oysters, Priv, Spring	339,600	96,786	99,700	31,106
Oysters, Priv, Fall	175,000	79,625	272,900	113,799
Total Invertebrates	2,702,700	507,500	2,315,200	470,735
Year Total	2,819,400	524,392	2,385,300	479,552

[1]Data from National Marine Fisheries Service, New Orleans Office.

Table 12. (Continued)

	1965		1966	
	Pounds	$ value	Pounds	$ value
Fish				
Black Drum	5,500	546	7.500	606
Black Mullet	500	25	500	22
Croaker	2,600	130	1,200	62
Flounder	5,500	870	4,000	660
Gar	2,100	105	900	67
King Whiting	6,400	690	9,900	703
Red Drum	10,100	1,815	12,900	2,193
Sawfish	---	---	---	---
Seacatfish	5,400	540	5,100	503
Seatrout, Spotted	11,600	3,104	18,100	4,319
Seatrout, White	---	---	4,000	439
Sheepshead	3,200	308	5,800	382
Spot	300	15	700	21
Tripletail	---	---	---	---
Total Fish	53,200	8,148	70,600	9,977
Invertebrates				
Blue Crab (Hard)	1,590,400	117,891	1,291,600	85,230
Blue Crab (Soft)	28,000	19,735	20,500	13,621
Shrimp (Heads On)	82,900	22,789	332,400	108,506
Oysters, Publ, Spring	---	---	---	---
Oysters, Publ, Fall	---	---	---	---
Oysters, Priv, Spring	12,600	6,317	38,800	16,227
Oysters, Priv, Fall	160,600	85,131	---	---
Total Invertebrates	1,874,500	251,863	1,683,300	223,584
Year Total	1,927,700	260,011	1,753,900	233,561

Table 12. (Continued)

	1967		1968	
	Pounds	$ value	Pounds	$ value
Fish				
Black Drum	7,100	467	18,100	1,252
Black Mullet	1,000	45	2,900	104
Croaker	3,400	286	2,600	207
Flounder	6,400	1,118	6,900	1,139
Gar	900	60	200	13
King Whiting	5,800	422	14,500	901
Red Drum	25,600	4,272	51,700	7,040
Sawfish	100	8	---	---
Seacatfish	3,400	295	---	---
Seatrout, Spotted	25,200	5,334	43,100	10,612
Seatrout, White	1,200	118	1,400	128
Sheepshead	10,300	629	---	---
Spot	700	38	---	---
Tripletail	200	19	---	---
Total Fish	91,200	13,111	141,400	21,396
Invertebrates				
Blue Crab (Hard)	1,269,400	88,948	1,664,400	139,270
Blue Crab (Soft)	30,500	25,536	58,500	47,156
Shrimp (Heads On)	650,800	153,947	460,900	114,941
Oysters, Publ, Spring	---	---	---	---
Oysters, Publ, Fall	---	---	---	---
Oysters, Priv, Spring	494,700	173,759	1,084,800	349,631
Oysters, Priv, Fall	179,500	109,620	739,300	430,938
Total Invertebrates	2,624,900	551,810	4,007,900	1,081,936
Year Total	2,716,100	564,921	4,149,300	1,103,332

Table 12. (Continued)

	1969		1970	
	Pounds	$ value	Pounds	$ value
Fish				
Black Drum	18,800	1,258	14,000	1,074
Black Mullet	5,500	171	1,800	87
Croaker	5,600	1,088	2,900	433
Flounder	6,800	1,097	7,700	1,275
Gar	1,200	93	800	56
King Whiting	12,100	1,021	8,900	477
Red Drum	42,800	6,206	41,200	6,678
Sawfish	---	---	---	---
Seacatfish	1,900	179	1,000	68
Seatrout, Spotted	36,000	10,746	34,600	9,621
Seatrout, White	700	91	700	51
Sheepshead	15,400	974	10,500	570
Spot	---	---	---	---
Tripletail	---	---	---	---
Total Fish	146,800	22,914	124,100	20,390
Invertebrates				
Blue Crab (Hard)	1,844,700	170,814	1,678,600	152,745
Blue Crab (Soft)	30,400	24,959	14,700	13,121
Shrimp (Heads On)	1,145,400	406,936	490,600	142,681
Oysters, Publ, Spring	---	---	---	---
Oysters, Publ, Fall	---	---	---	---
Oysters, Priv, Spring	769,200	299,442	580,800	220,106
Oysters, Priv, Fall	307,000	170,370	369,200	195,675
Total Invertebrates	4,096,700	1,072,521	3,133,900	724,328
Year Total	4,243,500	1,095,435	3,258,000	744,718

Table 12. (Continued)

	1971		1972	
	Pounds	$ value	Pounds	$ value
Fish				
Black Drum	12,000	1,122	8,900	878
Black Mullet	---	---	---	---
Croaker	---	---	---	---
Flounder	---	---	---	---
Gar	---	---	---	---
King Whiting	1,400	175	800	82
Red Drum	12,800	2,174	2,100	577
Sawfish	---	---	---	---
Seacatfish	---	---	---	---
Seatrout, Spotted	9,600	2,635	5,400	1,477
Seatrout, White	3,400	415	1,300	235
Sheepshead	2,500	173	1,700	100
Spot	---	---	---	---
Tripletail	---	---	---	---
Total Fish	41,700	6,694	20,200	3,349
Invertebrates				
Blue Crab (Hard)	537,200	65,280	1,127,100	140,320
Blue Crab (Soft)	13,400	13,671	4,000	4,322
Shrimp (Heads On)	394,000	125,606	640,500	317,027
Oysters, Publ, Spring	---	---	5,800	2,500
Oysters, Publ, Fall	---	---	---	---
Oysters, Priv, Soring	410,700	169,464	326,400	146,894
Oysters Priv, Fall	150,900	92,563	75,800	47,127
Total Invertebrates	1,506,200	466,584	2,179,600	658,190
Year Total	1,527,900	473,278	2,199,800	661,539

Table 12. (Continued)

	1973		1974	
	Pounds	$ value	Pounds	$ value
Fish				
Black Drum	5,700	647	1,800	202
Black Mullet	---	---	---	---
Croaker	---	---	---	---
Flounder	---	---	---	---
Gar	---	---	---	---
King Whiting	---	---	---	---
Red Drum	---	---	---	---
Sawfish	---	---	---	---
Seacatfish	---	---	---	---
Seatrout, Spotted	8,200	2,485	9,800	2,985
Seatrout, White	200	36	---	---
Sheepshead	800	66	---	---
Spot	---	---	---	---
Tripletail	---	---	---	---
Total Fish	14,900	3,234	11,600	3,187
Invertebrates				
Blue Crab (Hard)	713,400	81,488	263,100	37,920
Blue Crab (Soft)	3,100	3,370	---	---
Shrimp (Heads On)	169,400	83,053	250,700	66,518
Oysters, Publ, Spring	---	---	---	---
Oysters, Publ, Fall	19,000	5,166	24,700	21,701
Oysters, Priv, Spring	482,600	227,611	134,600	61,253
Oysters, Priv, Fall	170,700	121,101	88,400	71,910
Total Invertebrates	1,558,200	521,789	761,500	259,302
Year Total	1,573,100	525,023	773,100	262,489

Table 12. (Continued)

	1975	
	Pounds	$ value
Fish		
Black Drum	---	---
Black Mullet	---	---
Croaker	---	---
Flounder	---	---
Gar	---	---
King Whiting	---	---
Red Drum	---	---
Sawfish	---	---
Seacatfish	---	---
Seatrout, Spotted	---	---
Seatrout, White	---	---
Sheepshead	---	---
Spot	---	---
Tripletail	---	---
Total Fish	---	---
Invertebrates		
Blue Crab (Hard)	203,000	31,050
Blue Crab (Soft)	---	---
Shrimp (Heads On)	640,700	264,925
Oysters, Publ, Spring	---	---
Oysters, Publ, Fall	70,400	41,593
Oysters, Priv, Spring	171,000	83,961
Oysters, Priv, Fall	113,900	74,194
Total Invertebrates	1,199,000	495,723
Year Total	1,199,000	495,723

Table 13. Commercial Catches of Fish and Invertebrates from Lake Pontchartrain-Lake Borgne,[1] 1976-1977[2]

	1976		1977	
	Pounds	$ value	Pounds	$ value
Fish				
Black Drum	5,800	837	15,300	2,407
Buffalo	2,900	490	3,800	646
Catfish and Bullhead	39,000	17,435	100,300	46,655
Croaker	700	83	3,000	424
Flounder	400	153	1,400	543
Freshwater Drum	1,900	307	2,300	411
Gar	500	86	400	69
Mullet	---	---	2,700	218
Red Drum	24,100	7,932	29,300	9,059
Seacatfish	1,000	135	14,000	1,664
Seatrout, Spotted	14,800	6,652	34,200	17,351
Seatrout, White	2,700	457	1,600	328
Shad	50,000	2,500	35,000	1,750
Shark	100	21	59,600	5,956
Sheepshead	---	---	9,700	781
Spanish Mackerel	---	---	800	75
Total Fish	143,900	37,088	313,400	88,337
Invertebrates				
Blue Crab (Hard)	1,294,000	283,814	1,586,900	445,604
Blue Crab (Soft)	26,500	42,881	64,000	169,092
Shrimp (Heads on)	1,501,800	991,983	---	---
Oysters, Pub-Sp.	63,400	40,709	11,700	13,152
Oysters, Pub-F.	---	---	15,200	19,295
Oysters, Pr-Sp.	375,700	249,353	255,300	205,282
Oysters, Pr-F.	162,600	158,773	164,700	194,633
Total Invertebrates	3,424,000	1,767,513	2,097,800	1,047,058
Year Total	3,567,900	1,804,601	2,411,200	1,135,395

[1] Starting in 1976, Lake Pontchartrain catch data are combined with Lake Borgne catch data.

[2] Data from National Marine Fisheries Service, New Orleans Office.

contributed only .28% (by weight) and 1.15% (by value) to the total state for 1976 and 1977.

Although there are no estimates of the labor force in the Lake Pontchartrain fishery, catches may be declining because people are leaving the fishery force and thus total effort has been reduced because fewer people are fishing. With the strain of inflation pushing up production costs, fishermen could be moving into other fields as commercial fishing, which never was very extensive in the lake, becomes economically marginal.

POSSIBLE TRENDS

Some important questions regarding the commercial fish harvest of Lake Pontchartrain are: What are the trends of commercial fish harvest? Is the crab yield decreasing? Is the shrimp yield decreasing? Is the catfish yield decreasing? These questions are difficult to answer directly because Lake Pontchartrain is part of Hydrologic Unit I (or Catchment Basin) of coastal Louisiana, and commercial catch data are usually collected and presented in terms of Hydrologic Unit I and not for Lake Pontchartrain alone. In addition, the amount of effort for fish harvest in Lake Pontchartrain is not known or readily available. However, it is possible to test whether the fish harvest data from Lake Pontchartrain between 1963-1975 reflect random sampling.

Table 3 presents catch data from Lake Pontchartrain for 1963 to 1975. These data are given in Table 14 in terms of total pounds and the relationship this value has to the median value of the 13-year period. Using a one-sample run test (Tate and Clelland 1957), it is possible to test whether the sequence of the harvest data is random or if trends are

Table 14. Commercial Catch Totals (Fish, Crab, and Shrimp) from Lake Pontchartrain, LA, for 1963 to 1975, extracted from Table 3

Year	Pounds	Relationship To Median	Number of Runs
1963	1,162,500	above	1
1964	678,500	below	
1965	425,400	below	
1966	535,100	below	1
1967	679,400	below	
1968	628,100	below	
1969	805,300	below	
1970	1,002,100	median	
1971	1,317,100	above	
1972	1,130,200	above	
1973	2,103,400	above	1
1974	1,355,700	above	
1975	1,078,500	above	

median 1,002,100

Total Runs = 3
Number observations above median = 6
Number observations below median = 6

H_0 = random sampling; rejected at $p = 0.05$ for having too few runs (Tate and Clelland 1957).

evident. The hypothesis that the harvest data are the result of random sampling is rejected at the p = 0.05 level, since three or fewer runs indicate a significant departure from randomness.

Between 1964 and 1970, harvest data were always below the median 13-year value. Between 1971 and 1975, harvest were always above the median.

This preliminary analysis strongly suggests that there are definite trends in the fish harvest data of Lake Pontchartrain and that systematic factors are influencing them. In short, the fish harvest data are too clustered.

Run tests are nonparametric statistics and are designed for preliminary analysis to detect significant differences and thus indicate areas worthy of additional study.

Possible factors, and their proportion, involved in influencing fish harvest in Lake Pontchartrain have been discussed previously. However, future study should include a more detailed analysis of the data that would estimate harvest effort.

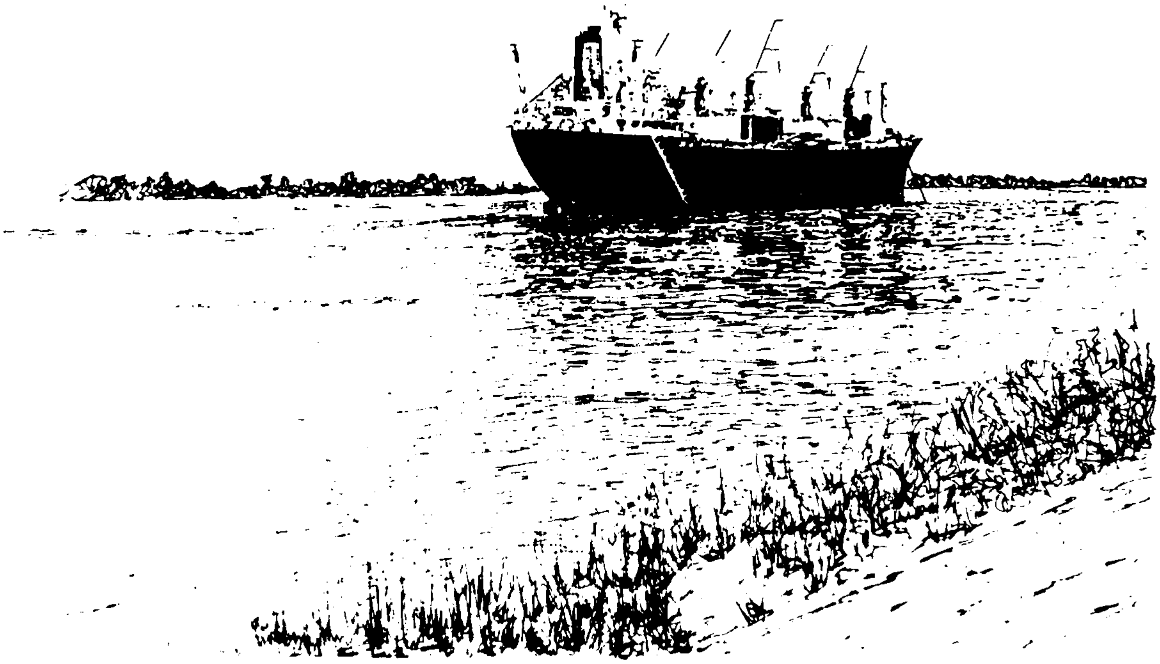
SUMMARY

The commercial catch figures for fish, crab, and shrimp are given for the Lake Pontchartrain-Lake Maurepas area for the 13-year period of 1963 to 1975. They are compared with the catches from both Lake Borgne and the state and are shown to contribute only 0.01% (by weight) and 0.10% (by value) to the total catch of Louisiana.

An analysis of environmental factors affecting the fish fauna of Lake Pontchartrain showed that many parameters influenced the commercial catch but no dominating increasing or decreasing trends were observed.

An important aspect facing the commercial fishing in Lake Pontchartrain is a potential decrease, through inflation, of the economic feasibility of continued commercial utilization of the lake. Inflation may rapidly be reaching a point where it will not pay to continued to fish the lake commercially.

Between 1964 and 1970, commercial fish harvest was significantly below the median 13-year value. Between 1971 and 1975, the harvest was significantly above the median. These data suggest systematic trends influencing fish harvest in Lake Pontchartrain, but present data do not allow identification of these factors.



Oceangoing freighter in the Intracoastal Waterway

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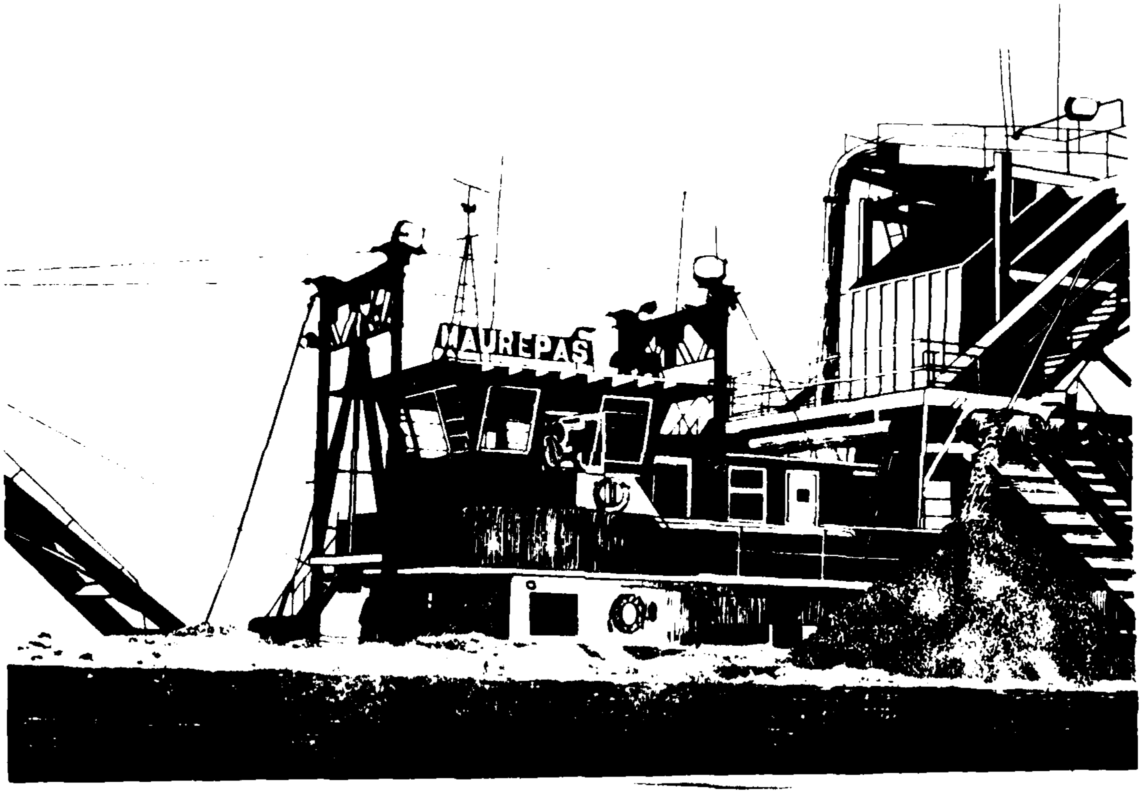

Pilot house of shell dredge

Chapter 17

PRELIMINARY SURVEY OF HIGHER VERTEBRATES OF LAKE PONTCHARTRAIN, LOUISIANA

by

James J. Hebrard
and
James H. Stone

ABSTRACT

A gradient of species richness exists for higher vertebrates among three macrohabitats in the Pontchartrain Basin. The gradient is relatively low in the lake itself, intermediate in the surrounding marshes, and highest in the forested wetlands. This gradient parallels a similar one for vegetation structure and possibly one for species richness of higher plants. All three habitats exhibit similar seasonal changes in the ratio of carnivores to omnivores and herbivores. During summer in all habitats, carnivores make up over 60 percent of the species, and true herbivores comprise the smallest fraction. Many of the carnivorous species primarily eat insects, which undoubtedly reach their greatest abundance in the warmer months. In winter, the proportion of carnivorous species declines, and the majority of species include some plant material in their diets. Many species are found in more than one habitat for a variety of reasons. Bats, for example, might use forested areas for roosting during the day and might feed over marsh and lake habitats at night. Other species, e.g., water snakes occur in a wide range of habitats without regard for changing vegetation structure.

INTRODUCTION

There are few systematic field surveys of vertebrates in wetland habitats of coastal Louisiana. Commercially important species have received some attention (e.g., Joanen and McNease 1972, Palmisano 1972), but these studies have concentrated on single species and thus are of limited utility in constructing a more integrated view of vertebrate community structure. This is a preliminary study of the trophic (or feeding) structure of vertebrates by major habitats in the Lake Pontchartrain Basin as derived from literature sources. Literature data are not adequate substitutes for careful fieldwork, but they can serve as a model against which field data may be tested. This study emphasizes spatial (macrohabitat) and temporal (seasonal) comparisons of vertebrate trophic relations. The discussion is limited to reptiles, birds, and mammals.

MATERIALS AND METHODS

I. Habitats

There are three major habitats in the Lake Pontchartrain Basin: forested wetlands, marshes, and the open water of the lake proper. The forested wetland habitat consists of at least two major habitat types: the drier, higher elevated bottomland hardwood forest and the lower, wetter, baldcypress-water tupelo swamp (see Penfound and Hathaway 1938). We have combined the two because of their more complicated vegetation structure when compared to marsh or lake. The marsh habitat can also be broken down, on the basis of salinity, into several types: fresh marsh at more inland locations and saline marsh near the coast (Chabreck 1972). The lack of trees and the general similarity of the vegetation

structure (low, herbaceous) partially justified the grouping of all marsh types into a single macrohabitat. Lake Pontchartrain was treated as a separate habitat; namely, the lake proper.

Only two seasons, summer and winter, were considered in this analysis. Reptiles were assumed to be completely inactive during the winter months although this might not be strictly true. For example, the water snake Nerodia cyclopion can be found to be active in every month of the year although it is very rare during the winter months and apparently does not feed (Mushinsky and Hebrard 1977, Hebrard and Mushinsky 1978). Few species of reptiles have been carefully studied in this regard in coastal Louisiana, but it is likely that even if some are active during the winter, their activity is probably drastically reduced. Choosing only two seasons for birds means that some periods of migration, when many species are only transient on the northern Gulf Coast, were not considered. It does not mean that migratory birds during these periods have small impact on or importance to the ecosystem.

II. Reptiles

A transparent overlay showing major vegetation zones of the Pontchartrain Basin was used in conjunction with original range maps (Dundee and Rossman, in preparation) to obtain species lists of lizards and snakes for each macrohabitat. Additional habitat and dietary data were obtained from Wright and Wright (1957). (Data in this handbook apply to the species as a whole, and information specific to the Pontchartrain Basin or even to Louisiana as a whole is extremely rare.) Species characteristics are known to vary geographically (e.g., Arnold 1977), thus reptile diets in the Pontchartrain Basin might be somewhat different from those obtained from general reference works. By combining food into more general

classes (e.g., insects, crustaceans), this difficulty is partially eliminated. Information on turtle diets and habitats was obtained from Carr (1952), and information on alligators specific to the northern Gulf Coast was taken from Chabreck (1972) and Joanen and McNease (1972).

III. Birds

Data on birds came from various sources, but the primary source for dietary information was A. C. Bent's Life Histories of North American Birds (1919-1968). Data on birds from Louisiana were rare, and thus the same constraints of geographic variation apply as did with reptiles. Much information was taken from Lowery (1974b), particularly details of seasonal abundance patterns. Some data on geographic distribution were taken from Robbins et al. (1966), and most habitat information was taken from Peterson (1963). Dietary data for diving ducks came primarily from Cottam (1939).

IV. Mammals

Lowery (1975a) was the primary source for mammal diet and habitat data. As with the reptiles, original range maps and vegetation overlays were used to estimate habitat distributions. Large-scale geographic distributions were obtained from range maps in Hall and Kelson (1959). Data specific to coastal Louisiana for muskrats and some other commercially important species are from O'Neil (1949) and Palmisano (1972).

V. Food Webs

Animal species were classified as carnivores, omnivores, or herbivores. Species were placed in the more specialized classes if the majority of their diet consisted of animals or plants, respectively. In cases where

quantitative data were available (for most birds), if over 90% of the diet was either plant or animal, the species was classified as a herbivore or carnivore. In the cases of qualitative descriptions, the judgement was more subjective. In constructing food webs, no weight was given to dietary items, and even if a particular species was known to consume only traces of a given food type, a connection was indicated. Connectivity was calculated for each habitat in each season using the following relationship:

$$\text{Connectivity index (or percent connection)} = \frac{\text{observed connections}}{\text{possible connections}} \times 100$$

RESULTS

I. Lake-Summer

Of the three habitats discussed in this paper, the lake itself has the most depauperate higher vertebrate fauna (cf., Tables 1, 2, 3); 21 species compared to 27 and 116 for marsh and forested wetlands. Species numbers are lowest during the summer, and the majority of higher vertebrates present at this time are carnivores. The connectivity index is 27%, the lowest of any habitat at either season, and probably indicates that the mean dietary breadths are relatively low (Tables 4 and A1, A2, and A3).

II. Lake-Winter

In winter, omnivores slightly outnumber carnivores (16 to 15 spp.) and more strictly herbivorous species are present (Table 1). This change is probably largely attributable to decreased activity of carnivorous reptiles and to the influx of many species of waterfowl that consume considerable amounts of plant material. The connection index at this

Table 1. Number of Species in Three Trophic Levels in Lake Habitat in Lake Pontchartrain, LA, During Summer and Winter

Season	Carnivores	Omnivores	Herbivores	Total
Summer	15 (71%)	5 (24%)	1 (5%)	21
Winter	15 (43%)	16 (46%)	4 (11%)	35

Scientific Name	Common Name
Lake Carnivores (Summer)	
Reptiles	
Alligator mississippiensis	American alligator
Nerodia cyclopion	Green water snake
N. rhombifera	Diamondback water snake
N. fasciata	Banded water snake
Regina rigida	Glossy water snake
Birds	
Anhinga anhinga	Anhinga
Larus atricilla	Laughing gill
Sterna forsteri	Forster's tern
S. albifrons	Least tern
S. caspia	Caspian tern
Chlidonias niger	Black tern
Stelgidopteryx ruficollis	Rough-winged swallow
Mammals	
Myotis austroriparius	Florida brown bat
Lasiurus borealis	Red bat
L. seminolus	Seminole bat
Lake Omnivores (Summer)	
Reptiles	
Chelydra serpentina	Snapping turtle
Macroclemys temmincki	Alligator snapping turtle
Malaclemys terrapin	Diamondback terrapin
Chrysemys scripta	Red-eared turtle
Birds	
Phalacrocorax olivaceus	Olivaceous cormorant

Table 1. (Continued)

Scientific Name	Common Name
Lake Herbivores (Summer)	
Mammals	
Myocastor coypus	Nutria
Lake Carnivores (Winter)	
Birds	
Pelecanus erythrorhynchus	White pelican
Phalacrocorax auritus	Double-crested cormorant
P. olivaceus	Olivaceous cormorant
Mergus serrator	Red-breasted merganser
Haliaeetus leucocephalus	Bald eagle
Falco peregrinus	Peregrine falcon
Larus argentatus	Herring gull
L. delawarensis	Ring-billed gull
L. atricilla	Laughing gull
L. philadelphia	Bonaparte's gull
Sterna forsteri	Forster's tern
S. hirundo	Common tern
S. caspia	Caspian tern
Megaceryle alcyon	Belted kingfisher
Iridoprocne bicolor	Tree swallow
Lake Omnivores (Winter)	
Birds	
Gavia immer	Common loon
Podiceps auritus	Horned grebe
P. nigricollis	Eared grebe
Podilymbus podiceps	Red-billed grebe
Anas acuta	Northern pintail
A. clypeata	Northern shoveler
Aythya americana	Redhead
A. collaris	Ring-necked duck
A. valisineria	Canvasback
A. marila	Greater scaup
A. affinis	Lesser scaup
Bucephala clangula	Common goldeneye
B. albeola	Bufflehead
Clangula hyemalis	Oldsquaw
Oxyura jamaicensis	Ruddy duck
Fulica americana	American coot

Table 1. (Continued)

Scientific Name	Common Name
Lake Herbivores (Winter)	
Birds	
Anas platyrhynchos	Mallard
A. crecca	Green-winged teal
A. americana	American widgeon
Mammals	
Myocastor coypus	Nutria

season rises to 36% as a consequence of greater dietary breadths (Table 4 and A1).

III. Marsh-Summer

With their combination of aquatic and semiterrestrial macrohabitats, marsh habitats surrounding Lake Pontchartrain support two to three times as many species of higher vertebrates as the lake itself (cf. Tables 1 and 2). Like those in the lake, the majority of higher marsh vertebrates in the summer are carnivores. This group includes not only numerous species of snakes but also a variety of carnivorous wading birds such as herons, egrets, and ibises. The connection index for the summer is 40% (Tables 4 and A2).

IV. Marsh-Winter

The general trophic structure of the marsh undergoes a change in the winter similar to that seen in the lake habitat; i.e., the proportion of carnivores drops and that of omnivores and herbivores rises (Table 2). The number of bird species more than doubles during the winter and includes 14 species of herbivorous and omnivorous waterfowl not present in the summer. The three species of insect-eating bats that feed over the marsh during the warm months are not present in winter and what remains are 12 species of mammals, 9 of which consume at least some vegetable material. The marsh connection index does not change appreciably during the winter and is 38% (Table 4 and A2).

V. Forested Wetland-Summer

With its complex vegetation structure, including large trees, the summer forested wetland habitat has the greatest higher vertebrate

Table 2. Number of Species in Three Trophic Levels in Marsh Habitats in Lake Pontchartrain, LA, During Summer and Winter

Season	Carnivores	Omnivores	Herbivores	Total
Summer	44 (66%)	20 (30%)	3 (4%)	67
Winter	33 (47%)	27 (39%)	10 (14%)	70

Scientific Name	Common Name
Marsh Carnivores (Summer)	
Amphibians	
Hyla cinerea	Green tree frog
Rana catesbeiana	Bullfrog
Reptiles	
Alligator mississippiensis	American alligator
Kinosternon subrubrum	Mudturtle
Nerodia cyclopion	Green water snake
N. rhombifera	Diamondback water snake
N. erythrogaster	Red-bellied water snake
N. fasciata	Banded water snake
Regina grahamii	Graham's water snake
R. rigida	Glossy water snake
Storeria dekayi	Brown snake
Thamnophis sirtalis	Common garter snake
T. sauritus	Eastern ribbon snake
T. proximus	Western ribbon snake
Farancia abacura	Mud snake
Coluber constrictor	Black racer
Lampropeltis getulus	Eastern king snake
Agkistrodon piscivorus	Cottonmouth moccasin
Birds	
Ardea herodias	Great blue heron
Butorides striatus	Striated green heron
Florida caerulea	Little blue heron
Bubulcus ibis	Cattle egret
Casmerodius albus	Common egret
Egretta thula	Snowy egret
Hydranassa tricolor	Louisiana heron
Nycticorax nycticorax	Black crowned night heron
Nyctanassa violacea	Yellow crowned night heron
Ixobrychus exilis	Least bittern
Mycteria americana	Wood ibis
Plegadis falcinellus	Glossy ibis
P. chihi	White-faced ibis
Eudocimus albus	White ibis

Table 2. (Continued)

Scientific Name	Common Name
Marsh Carnivores (Summer) - Continued	
Birds	
Himantopus mexicanus	Black-neck stilt
Larus atricilla	Laughing gull
Sterna forsteri	Foster's fern
Cistothorus palustrisu	Long-billed marsh wren
Geothiypis trichas	Yellow throat
Quiscalus major	Boat-tailed grackle
Mammals	
Myotis austroriparius	Florida brown bat
Lasiurus borealis	Red bat
L. seminolus	Seminole bat
Mustela vison	Mink
Mephitis mephitis	Striped skunk
Lutra canadensis	River otter
Marsh Omnivores (Summer)	
Reptiles	
Chelydra serpentina	Snapping turtle
Sternotherus odoratus	Stinkpot
Malaclemys terrapin	Diamondback terrapin
Chrysemys scripta	Red-eared turtle
C. picta	Painted turtle
Deirochelys reticularia	Chicken turtle
Birds	
Anas fulvigula	Mottled duck
Rallus elegans	King rail
R. longirostris	Clapper rail
Porphyrula martinica	Purple Gallinule
Catoptropherus semipalmatus	Willet
Corvus ossifragus	Fish crow
Agelaius phoeniceus	Red-winged blackbird
Ammospiza maritima	Seaside sparrow
Mammals	
Didelphis virginiana	Opossum
Dasypus novemcinctus	Nine-banded armadillo
Oryzomys palustris	Marsh rice rat
Sigmodon hispidus	Cotton rat
Ondatra zibethicus	Muskrat
Procyon lotor	Raccoon

Table 2. (Continued)

Scientific Name	Common Name
Marsh Herbivores (Summer)	
Mammals	
Sylvilagus aquaticus	Swamp rabbit
Myocastor coypus	Nutria
Odocoileus virginianus	White-tailed deer
Marsh Carnivores (Winter)	
Birds	
Podilymbus podiceps	Pied-billed grebe
Pelecanus erythrorhynchus	White pelican
Ardea herodias	Great blue heron
Bubulcus ibis	Cattle egret
Casmerodius albus	Common egret
Egretta thula	Snowy egret
Hydranassa tricolor	Louisiana heron
Botaurus lentiginous	American bittern
Plegadis falcinellus	Glossy ibis
P. chihi	White-faced ibis
Eudocimus albus	White ibis
Lophodytes cucullatus	Hooded merganser
Circus cyaneus	Marsh hawk
Falco peregrinus	Peregrine falcon
F. columbarius	Pigeon hawk
F. sparverius	Sparrow hawk
Rallus limicola	Virginia rail
Pluvialis squatarola	Black-bellied plover
Capella gallinago	Common snipe
Calidris mauri	Western sandpiper
C. minutilla	Least sandpiper
C. alpina	Dunlin
Larus atricilla	Laughing gull
Gelochelidon nilotica	Gull-billed tern
Sterna forsteri	Foster's tern
Asio flammeus	Short-eared owl
Megaceryle alcyon	Belted kingfisher
Cistothorus palustris	Long-billed marsh wren
C. platensis	Short-billed marsh wren
Quiscalus major	Boat-tailed grackle
Mammals	
Mustela vison	Mink
Mephitis mephitis	Striped skunk
Lutra canadensis	River otter

Table 2. (Continued)

Scientific Name	Common Name
Marsh Omnivores (Winter)	
Birds	
Anas fulvigula	Mottled duck
A. acuta	Pintail
A. discors	Blue-winged teal
A. clypeata	Shoveler
Aythya collaris	Ring-necked duck
Oxyura jamaicensis	Ruddy duck
Rallus elegans	King rail
R. longirostris	Clapper rail
Porzana carolina	Sora
Fulica americana	American coot
Recurvirostra americana	American avocet
Catoptropherus semipalmatus	Willet
Limnodromus sclopaceus	Long-billed dowitcher
Iridoprocne bicolor	Tree swallow
Corvus ossifragus	Fish crow
Anthus spinoletta	Water pipet
Agelaius phoeniceus	Red-winged blackbird
Ammospiza caudacuta	Sharp-tailed sparrow
A. maritima	Seaside sparrow
Melospiza georgiana	Swamp sparrow
M. melodia	Song sparrow
Mammals	
Didelphis virginiana	Oppossum
Dasypus novemcinctus	Nine-banded armadillo
Oryzomus palustris	Marsh rice rat
Signodon hispidus	Cotton rat
Ondatra zibethicus	Muskrat
Procyon lotor	Raccoon
Marsh Herbivores (Winter)	
Birds	
Anser albifrons	White-fronted goose
Chen caerulescens	Blue goose
Anas platyrhynchos	Mallard
A. strepera	Gadwall
A. crecca	Common teal
A. americana	American widgeon
Passerculus sandwichensis	Savannah sparrow
Mammals	
Sylvilagus aquaticus	Swamp rabbit
Myocastor coypus	Nutria
Odocoileus virginianus	White-tailed deer

species richness of all (cf. Tables 1, 2, and 3). In addition to many of the same species present in the marsh, the complex physical structure of the forest probably provides additional kinds of ecological niches. Terrestrial or arboreal lizards and snakes as well as such bird groups as woodpeckers, owls, hawks, and numerous arboreal songbirds are present. Squirrels and several terrestrial rodents increase the mammal fauna over that of the marsh. During the summer, the majority of higher vertebrates in the forests are carnivorous. This group includes 21 species of lizards and snakes, 11 species of wading birds, 9 species of birds of prey, 27 species of partly or wholly insectivorous songbirds, 3 species of bats, and 4 other species of entirely carnivorous mammals. The connection index of 36% is similar to that of the marsh (Table 4).

VI. Forested Wetlands-Winter

The forested wetlands habitat undergoes a change in winter similar to that seen in marsh and lake, i.e., the number of carnivorous species declines while omnivorous and herbivorous species increase (Table 3). The decline in carnivores is partly attributable to the relative inactivity of the 21 species of lizards and snakes characteristic of this habitat. Other contributing factors are the migration of 14 insectivorous songbirds to tropical areas for the winter and the migration or inactivity of 3 species of insectivorous bats. In the winter, 18 species of birds arrive that include some vegetable material in their diets. Notable among these are 6 species of seed-eating finches. The winter connection index of 40% is only slightly higher than that of the summer community (Table 4) and is equal to the summer and almost equal to the winter marsh and lake communities.

Table 3. Number of Species in Three Trophic Levels in Forested Wetlands Surrounding Lake Pontchartrain, LA, during Summer and Winter

Season	Carnivores	Omnivores	Herbivores	Total
Summer	72 (62%)	37 (32%)	7 (6%)	116
Winter	26 (34%)	40 (53%)	10 (13%)	76

Scientific Name	Common Name
Forested Wetlands Carnivores (Summer)	
Birds	
Anhinga anhinga	Anhinga
Ardea herodias	Great blue heron
Butorides striatus	Striated green heron
Florida caerulea	Little blue heron
Casmerodius albus	Common egret
Egretta thula	Snowy egret
Hydranassa tricolor	Louisiana heron
Nycticorax nycticorax	Black crowned night heron
Nyctanassa violacea	Yellow crowned night heron
Ixobrychus exilis	Least bittern
Mycteria americana	Wood ibis
Eudocimus albus	White ibis
Eleanoides forficatus	Swallow-tailed kite
Ictinia misisippiensis	Mississippi kite
Accipiter cooperi	Cooper's hawk
Buteo lineatus	Red-shouldered hawk
B. platypterus	Broad-winged hawk
Coccyzus americanus	Yellow-billed cuckoo
Tyto alba	Barn owl
Otus asio	Screech owl
Bubo virginianus	Great horned owl
Strix varia	Barred owl
Chaetura pelagica	Chimney swift
Myiarchus crinitus	Great crested flycatcher
Empidonax virescens	Acadia flycatcher
Contopus virens	Eastern wood pewee
Thryothorus ludovicianus	Carolina wren
Polioptila caerulea	Blue-gray gnatcatcher
Vireo griseus	White-eyed vireo
V. flavifrons	Yellow-throated viero
Parula americana	Parula warbler
Dendroica dominica	Yellow-throated warbler
Limnothlypis swainsonii	Swainson's warbler
Protonotaria citrea	Prothonotary warbler
Geothlypis trichas	Yellowthroat
G. formosa	Kentucky warbler
Wilsonia citrina	Hooded warbler

Table 3. (Continued)

Scientific Name	Common Name
Forrested Wetlands Carnivores (Summer) - Continued	
Mammals	
Myotis austroriparius	Florida brown bat
Lasiurus borealis	Red bat
L. seminolus	Seminole bat
Mustela vison	Mink
Mephitis mephitis	Striped skunk
Lutra canadensis	River otter
Lynx rufus	Bobcat
Herptiles	
Macroclemys temmincki	Alligator snapping turtle
Hyla cinerea	Green tree frog
Rana catesbeiana	Bullfrog
Alligator mississippiensis	American alligator
Sternotherus odoratus	Stinkpot
Kenosternon subrubrum	Mud turtle
Anolis carolinensis	Green anole
Scincella laterale	Ground skink
Eumeces fasciatus	Five-lined skink
E. laticeps	Broad-headed skink
Nerodia cyclopion	Green water snake
N. rhombifera	Diamondback water snake
N. erythrogaster	Red-bellied water snake
N. sipedon	Northern water snake
N. fasciata	Banded water snake
Regina grahamii	Graham's water snake
R. rigida	Glossy water snake
Thamnophis sirtalis	Common garter snake
T. proximus	Western ribbon snake
Farancia abacura	Mud snake
Coluber constrictor	Black racer
Opheodrys aestivus	Rough green snake
Elaphe obsoleta	Black rat snake
Lampropeltis getulus	Eastern king snake
Micrurus fulvius	Eastern coral snake
Agkistrodon contortrix	Copperhead
A. piscivorus	Cottonmouth moccasin
Crotalus horridus	Timber rattlesnake
Forested Wetlands Omnivores (Summer)	
Birds	
Porphyrula martinica	Purple gallinule
Archilochus colubris	Ruby-throated hummingbird
Colaptes auratus	Yellow-shafted flicker

Table 3. (Continued)

Scientific Name	Common Name
Forested Wetlands Omnivores (Summer) - Continued	
Birds	
Dryocopus pileatus	Pileated woodpecker
Melanerpes carolinus	Red-bellied woodpecker
Picoides villosus	Hairy woodpecker
P. pubescens	Downy woodpecker
Cyanocitta cristata	Blue jay
Corvus brachyrhynchos	Common crow
C. ossifragus	Fish crow
Parus carolinensis	Carolina chickadee
P. bicolor	Tufted titmouse
Toxostoma rufum	Brown thrasher
Hylocichla mustelina	Wood thrush
Vireo olivaceus	Red-eyed vireo
Agelarius phoeniceus	Red-winded blackbird
Quiscalus quiscula	Common grackle
Molothrus ater	Brown-headed cowbird
Piranga rubra	Summer tanager
Cardinalis cardinalis	Cardinal
Pipilo erythophthalmus	Rufous-sided towhee
Mammals	
Didelphis virginiana	Opossum
Blarina brevicauda	Short-tailed shrew
Dasypus novemcinctus	Nine-banded armadillo
Sylvilagus floridanus	Cottontail rabbit
Sciurus niger	Fox squirrel
Glaucomys volans	Southern flying squirrel
Oryzomys palustris	Marsh rice rat
Neotoma floridana	Eastern wood rat
Ondatra zibethicus	Muskrat
Myocastor coypus	Nutria
Urocyon cineroargenteus	Gray fox
Procyon lotor	Raccoon
Reptiles	
Chelydra serpentina	Snapping turtle
Terrapene carolina	Box turtle
Chrysemsy picta	Painted turtle
Deirochelys reticularia	Chicken turtle
Forested Wetlands Herbivores (Summer)	
Birds	
Aix sponsa	Wood duck
Sylvilagus aquaticus	Swamp rabbit
Sciurus carolinensis	Gray squirrel

Table 3. (Continued)

Scientific Name	Common Name
Forested Wetlands Herbivores (Summer) - Continued	
Mammals	
Peromyscus gossypinus	Cotton mouse
Myocastor coypus	Nutria
Odocoileus virginianus	White-tailed deer
Reptiles	
Chrysemys scripta	Red-eared turtle
Forested Wetlands Carnivores (Winter)	
Birds	
Casmerodius albus	Common egret
Egretta thula	Snowy egret
Hydranassa tricolor	Louisiana heron
Botaurus lentiginosus	American bittern
Eudocimus albus	White ibis
Lophodytes cucullatus	Hooded merganser
Accipiter cooperi	Cooper's hawk
Buteo lineatus	Red-shouldered hawk
Rallus elegans	King rail
Porzana carolina	Sora
Philohela minor	American woodcock
Tyto alba	Barn owl
Otus asio	Screech owl
Bubo virginianus	Great horned owl
Strix varia	Barred owl
Megaceryle alcyon	Belted kingfisher
Certhia familiaris	Brown creeper
Troglodytes aedon	House wren
T. troglodytes	Winter wren
Thryothorus ludovicianus	Carolina wren
Regulus satrapa	Golden-crowned kinglet
R. calendula	Ruby-crowned kinglet
Mammals	
Mustela vison	Mink
Mephites mephites	Striped skunk
Lutra canadensis	River otter
Lynx rufus	Bobcat

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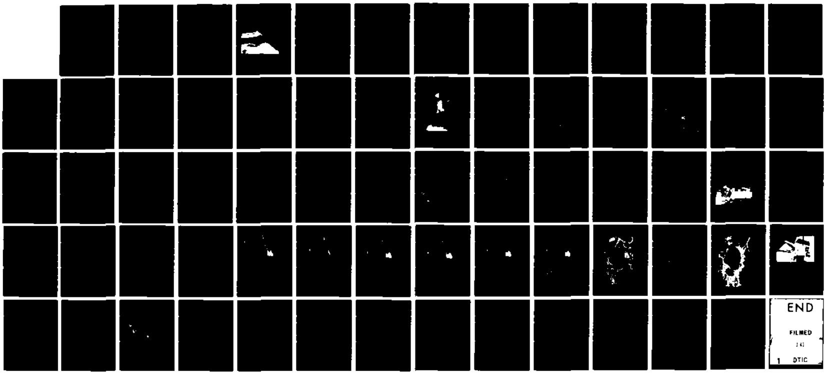

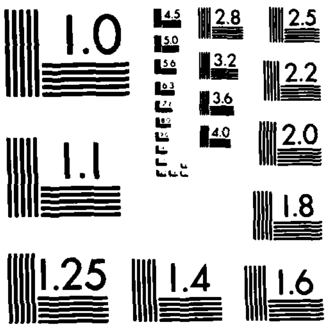

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Table 3. (Continued)

Scientific Name	Common Name
Forested Wetlands Omnivores (Winter)	
Birds	
Porzana carolina	Sora
Colaptes auratus	Yellow-shafted flicker
Dryocopus pileatus	Pileated woodpecker
Melanerpes carolinus	Red-bellied woodpecker
Sphyrapicus varius	Yellow-bellied sapsucker
Picoides villosus	Hairy woodpecker
P. pubescens	Downy woodpecker
Sayornis phoebe	Eastern phoebe
Cyanocitta cristata	Blue jay
Corvus brachyrhynchos	Common crow
C. ossifragus	Fish crow
Parus carolinensis	Carolina chickadee
P. bicolor	Tufted titmouse
Toxostoma rufum	Brown thrasher
Turdus migratorius	Robin
Catharus guttata	Hermit thrush
Bombycilla cedorum	Cedar waxwing
Vireo solitarius	Solitary vireo
Vermivora celata	Orange-crowned warbler
Dendroica coronata	Myrtle warbler
Agelarius phoeniceus	Red-winged blackbird
Euphagus carolinas	Rusty blackbird
Quiscalus quiscula	Common grackle
Molothrus ater	Brown-headed cowbird
Cardinalis cardinalis	Cardinal
Pipilo erythophthalmus	Rufous-sided towhee
Melospiza lincolnii	Lincoln's sparrow
M. georgiana	Swamp sparrow
M. melodia	Song sparrow
Mammals	
Didelphis virginiana	Opossum
Blarina brevicauda	Short-tailed shrew
Dasypus novemcinctus	Nine-banded armadillo
Sylvilagus floridanus	Cottontail rabbit
Sciurus niger	Fox squirrel
Glaucomys volans	Southern flying squirrel
Oryzomys palustris	Marsh rice rat
Neotoma floridana	Eastern wood rat
Ondatra zibethicus	Muskrat
Urocyon cinereoargenteus	Gray fox
Procyon lotor	Raccoon

Table 3. (Continued)

Scientific Name	Common Name
Forested Wetlands Herbivores (Winter)	
Birds	
Anas platyrhynchos	Mallard duck
Aix sponsa	Wood duck
Carpodacus purpureus	Purple finch
Carduelis tristis	American goldfinch
Zonotrichia albicollis	White-throated sparrow
Mammals	
Sylvilagus aquaticus	Swamp rabbit
Sciurus carolinensis	Gray squirrel
Peromyscus gossypinus	Cotton mouse
Myocastor coypus	Nutria
Odocoileus virginianus	White-tailed deer

Table 4. Food-web Connectivity for Habitats of Lake Pontchartrain and Its Surrounding Wetlands; Connectivity is Defined as

$$\text{Percent Connection or (Connectivity)} = \frac{\text{Observed Connections}}{\text{Possible Connections}} \times 100\%$$

	Lake	Marsh	Forested Wetlands
Summer	27	40	36
Winter	36	38	40

Loading rangia shells on barge from dredge

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APPENDIX

Detailed Listings of Vertebrate Species and Food Types from Lake Pontchartrain, LA

Table 1A. Detailed Listing of Vertebrate Species Found in Lake Pontchartrain, LA, During Summer. The Numbers Before Each Species Indicate Which of the 10 General Food Types Each is Known to Use

Food Types Used	Species: Scientific Name	Species: Common Name
Mammals		
1	*Myocastor coypus*	Nutria
5	*Myotis austroriparius*	Southeastern bat
5	*Lasiurus borealis*	Red bat
5	*L. seminolus*	Seminole bat
Birds		
5	*Stelgidopteryx ruficollis*	Rough-winged swallow
5,6	*Chlidonias niger*	Black tern
4,6	*Sterna caspia*	Caspian tern
4,5,6	*S. albifrons*	Least tern
5,6	*S. forsteri*	Forster's tern
6	*Larus atricilla*	Laughing gull
2,4,5,6,7,8	*Anhinga anhinga*	Anhinga
1,3,4,6	*Phalacrocorax olivaceus*	Olivaceus comorant
Reptiles		
4	*Regina rigida*	Glossy water snake
6,7	*Nerodia fasciata*	Banded water snake
6,7	*N. rhombifera*	Diamondback snake
6	*N. cyclopion*	Green water snake
1,4,5	*Chrysemys scripta*	Red-eared turtle
1,3,4	*Malaclemys terrapin*	Diamondback terrapin
1,3,6,7,8	*Macroclemys temmincki*	Alligator snapping turtle
1,2,3,4,5,6,8,9,10	*Chelydra serpentina*	Snapping turtle
1,3,4,6,8,10	*Alligator mississippiensis*	American alligator

Observed connections = 56
Possible connections = 210
Connectivity index = 27%

The 10 food types are:

(1) aquatic plants	(6) fish
(2) worms	(7) amphibians
(3) mollusks	(8) reptiles
(4) crustaceans	(9) birds
(5) insects	(10) mammals

Table 2A. Detailed Listing of Vertebrate Species Found in Lake Pontchartrain, LA, During Winter. The Numbers Before Each Species Indicate Which of the 10 General Food Types Each is Known to Use

Food Types Used	Species: Scientific Name	Species: Common Name
Birds		
1,3,4,6	*Phalacrocorax auritus*	Double-crested cormorant
1,3,4,6	*P. olivaceus*	Olivaceus cormorant
3,4,6	*Mergus serrator*	Red-breasted merganser
6,8,9,10	*Haliaeetus leucocephalus*	Bald eagle
5,9,10	*Falco peregrinus*	Peregrine falcon
2,3,4,5,6	*Larus argentatus*	Herring gull
5	*L. delawarensis*	Ring-billed gull
6,9	*L. atricilla*	Laughing gull
2,4,5,6	*L. philadelphia*	Bonaparte's gull
5	*Sterna forsteri*	Forster's tern
4,5,6	*S. hirundo*	Common tern
4,6	*S. caspia*	Caspian tern
1,3,4,5,6,7,8,9,10	*Megaceryle alcyon*	Belted kingfisher
1,5	*Iridoprocne bicolor*	Tree swallow
1,4,6	*Gavia immer*	Common loon
1,4,6	*Podiceps auritus*	Horned grebe
1,4,5	*P. nigrocollis*	Eared grebe
1,2,3,5,6,7	*Podilymbus podiceps*	Pied-billed grebe
1,2,3,4	*Anas acuta*	Northern pintail
1,2,3,4,5,6,7	*A. clypeata*	Northern shoveler
1	*Aythya americana*	Redhead
1,3,5	*A. collaris*	Ring-necked duck
1,3,4,5,6	*A. valisineria*	Canvasback
1,3,4	*A. marila*	Greater scaup
1,3,4	*A. affinis*	Lesser scaup
1,3,4,5,6	*Bucephala clangula*	Common goldeneye
1,3,4,5,6	*B. albeola*	Bufflehead
1,3,4,5,6	*Clangula hyemalis*	Old squaw
1,3,4,5	*Oxyura jamaicensis*	Ruddy duck
1,2,3,5,6,7	*Fulica americana*	American coot
1,3,4,5,6	*Anas platyrhynchos*	Mallard
1,3,4,5	*A. crecca*	Green-winged teal
1	*A. americana*	American widgeon

The 10 food types are:

(1) aquatic plants
(2) worms
(3) mollusks
(4) crustaceans
(5) insects
(6) fish
(7) amphibians
(8) reptiles
(9) birds
(10) mammals

Table 2A. (Continued)

Food Types Used	Species Scientific Name	Common Name
Mammals		
1	*Myocastor coypus*	Nutria

Observed connections = 125
Possible connections = 350
Connectivity index = 36%

The 10 food types are:

(1) aquatic plants	(6) fish
(2) worms	(7) amphibians
(3) mollusks	(8) reptiles
(4) crustaceans	(9) birds
(5) insects	(10) mammals

Table 3A. Detailed List of Vertebrate Species Found in Marshes of Lake Pontchartrain, LA, During Summer. The Numbers Before Each Species Indicate Which of the 10 General Food Types Each is Known to Use

Food Types Used	Species: Scientific Name	Species: Common Name
Reptiles		
1,3,4,6,10	*Alligator mississippiensis*	American alligator
3,5	*Kinosternon subrubrum*	Mud turtle
6	*Nerodia cyclopion*	Green water snake
4,6,7	*N. rhombifera*	Diamondback water snake
4,6,7	*N. erythrogaster*	Red-bellied water snake
4,5,6,7	*N. fasciata*	Banded water snake
4	*Regina grahamii*	Graham's water snake
4	*R. regida*	Glossy water snake
2,3,5,6,7	*Storeria dekayi*	Brown snake
2,3,5,6,7,9,10	*Thamnophis sirtalis*	Common garter snake
?	*T. sauritus*	Eastern ribbon snake
5,6,7,10	*T. proximus*	Western ribbon snake
7	*Farancia abacura*	Mud snake
5,7,8,9,10	*Coluber constrictor*	Black racer
8,9,10	*Lampropeltis getulus*	Eastern king snake
6,7,8,9,10	*Agkistrodon piscivorus*	Cottonmouth moccasin
1,2,3,4,5,6,8,9,10	*Chelydra serpentina*	Snapping turtle
1,3,4,5,6	*Sternotherus odoratus*	Stinkpot
1,3,4	*Malaclemys terrapin*	Diamondback terrapin
1,4,5	*Chrysemys scripta*	Red-eared turtle
1,2,3,4,5,6	*C. picta*	Painted turtle
1,4,7	*Deirochelys reticularia*	Chicken turtle
Birds		
4,5,6,7,8,9,10	*Ardea herodias*	Great blue heron
2,4,5,6,7,8,10	*Butorides striatus*	Striated green heron
4,5,6,7,8	*Florida caerulea*	Little blue heron
5	*Bubulcus ibis*	Cattle egret
1,3,4,5,6,7,8,10	*Casmerodius albus*	Common egret
3,4,5,6,7,8	*Egretta thula*	Snowy egret
2,3,4,5,6,7,8	*Hydranassa tricolor*	Louisiana heron
2,4,5,6	*Nycticorax nycticorax*	Black-crowned night heron
3,4,6,8,9,10	*Nyctanassa violacea*	Yellow-crowned night heron
2,3,4,5,6,7,8,10	*Ixobrychus exilis*	Least bittern
5,6,8	*Mycteria americana*	Wood ibis
4,5,8	*Plegadis falcinellus*	Glossy ibis
2,3,4,5,6,7	*P. chihi*	White-faced ibis
3,4,5,8	*Eudocimus albus*	White ibis
1,3,4,5,6	*Himantopus mexicanus*	Black-necked stilt
6,9	*Larus atricilla*	Laughing gull

The 10 food types are:

(1) aquatic plants
(2) worms
(3) mollusks
(4) crustaceans
(5) insects
(6) fish
(7) amphibians
(8) reptiles
(9) birds
(10) mammals

Table 3A. (Continued)

Food Types Used	Species: Scientific Name	Species: Common Name
Birds (Continued)		
5	Sterna forsteri	Forster's tern
5	Cistothorus palustris	Long-billed marsh wren
1,5	Geothlypis trichas	Yellow throat
5,6,7	Quiscalus major	Boat-tailed grackle
1,3,4,5,6	Anas fulvigula	Mottled duck
1,2,3,4,5,7	Rallus elegans	King rail
1,3,4,5,6	R. longirostris	Clapper rail
1,2,3	Porphyrula martinica	Purple gallinule
1,2,3,4,5,6	Catopthrophorus semipalmatus	Willet
1,4,6,9	Corvus ossifragus	Fish crow
1,5	Agelaius phoeniceus	Red-winged bl bird
1,2,3,4,5	Ammospiza maritima	Seaside sparr
Mammals		
5	Myotis austroriparius	Southeastern bat
5	Lasiurus borealis	Red bat
5	L. seminolus	Seminole bat
4,6,7,9,10	Mustela vison	Mink
4,5,7,10	Mephitis mephitis	Striped skunk
4,6,7,8	Lutra canadensis	River otter
1,5,9	Didelphis virginiana	Opossum
1,5	Dasypus novemcinctus	Armadillo
1,4,5,9	Oryzomys palustris	Marsh rice rat
1,4,5,9	Sigmodon hispidus	Cotton rat
1,3,5,6	Ondatra zibethicus	Muskrat
1,3,4,5,6,7,8,9	Procyon lotor	Raccoon
1	Sylvilagus aquaticus	Swamp rabbit
1	Myocastor coypus	Nutria
1	Odocoileus virginianus	White-tailed deer

Observed connections = 260
Possible connections = 650
Connectivity index = 40%

The 10 food types are:

(1) aquatic plants
(2) worms
(3) mollusks
(4) crustaceans
(5) insects
(6) fish
(7) amphibians
(8) reptiles
(9) birds
(10) mammals

Table 4A. Detailed List of Vertebrate Species Found in Marsh Habitat of Lake Pontchartrain, LA, During Winter. The Numbers Before Each Species Indicate Which of the 10 General Food Types Each is Known to Use

Food Types Used	Species: Scientific Name	Species: Common Name
Birds		
1,2,3,5,6,7	Podilymbus podiceps	Pied-billed grebe
6	Pelecanus erythrorhynchus	White pelican
4,5,6,7,8,9,10	Ardea herodias	Great blue heron
5	Bubulcus ibis	Cattle egret
1,3,4,5,6,7,8,10	Casmerodius albus	Common egret
3,4,5,6,7,8	Egretta thula	Snowy egret
2,3,4,5,6,7,8	Hydranassa tricolor	Louisiana heron
3,4,5,6,7,8,10	Botaurus lentiginosus	American bittern
4,5,8	Plegadis falcinellus	Glossy ibis
2,3,4,5,6,7	P. chihi	White-faced ibis
3,4,5,8	Eudocimus albus	White ibis
1,3,4,5,6,7	Lophodytes cucullatus	Hooded merganser
9,10	Circus cyaneus	Marsh hawk
5,9,10	Falco peregrinus	Peregrine falcon
5,7,8,9,10	F. columbarius	Pigeon hawk
5,7,8,9,10	F. sparverius	Sparrow hawk
1,2,3,4,5,6	Rallus limicola	Virginia rail
1,2,3,4,5	Pluvialis squatarola	Black-bellied plover
1,2,5	Capella gallinago	Common snipe
2,3,5	Calidris mauri	Western Sandpiper
2,4,5	C. minutilla	Least sandpiper
1,2,3,4,5	C. alpina	Dunlin
6,9	Larus atricilla	Laughing gull
5	Gelochelidon nilotica	Gull-billed tern
5	Sterna forsteri	Forster's tern
5,9,10	Asio flammeus	Short-eared owl
1,3,4,5,6,7,8,9,10	Megaceryle alcyon	Belted kingfisher
5	Cistothorus palustris	Long-billed marsh wren
5	C. platensis	Short-billed marsh wren
5,6,7	Quiscalus major	Boat-tailed grackle
1,3,4,5,6	Anas fulvigula	Mottled duck
1,2,3,4	A. acuta	Pintail
1,2,3,5,7	A. discors	Blue-winged teal
1,2,3,4,5,6,7	A. clypeata	Shoveler
1,3,5	Aythya collaris	Ring-necked duck
1,3,4,5	Oxyura jamaicensis	Ruddy duck
1,2,3,4,5,7	Rallus elegans	King rail
1,3,4,5,6	R. longirostris	Clapper rail
1,2,3,5,6,7	Porzana carolina	Sora

The 10 food types are:

(1) aquatic plants (2) worms (3) mollusks (4) crustaceans (5) insects (6) fish (7) amphibians (8) reptiles (9) birds (10) mammals

Table 4A. (Continued)

Food Types Used	Species Scientific Name	Common Name
Birds (Continued)		
1,5	Fulica americana	American coot
1,2,3,4,5,6	Recurvirostra americana	Americant avocet
1,5	Catoptrophorus semipalmatus	Willet
1,5	Limnodromus scolopaceus	Long-billed dowitcher
1,4,6,9	Iridoprocne bicolor	Tree swallow
1,3,4,5	Corvus ossifragus	Fish crow
1,5	Anthus spinoletta	Water pipet
1,3,4,5	Agelaius phoeniceus	Red-winged blackbird
1,2,3,4,5	Ammospiza caudacuta	Sharp-tailed sparrow
1,5	A. maritima	Seaside sparrow
1,5	Melospiza georgiana	Swamp sparrow
1,5	M. melodia	Song sparrow
1,3,5	Anser albifrons	White-faced goose
1,3,4,5,6	Chen caerulescens	Blue goose
1	Anas platyrhynchos	Mallard
1,3,4,5	A. strepera	Gadwall
1	A. crecca	Common teal
1,5	Passerculus sandwichensis	Savannah sparrow
Mammals		
4,6,7,9,10	Mustela vison	Mink
4,5,7,10	Mephitis mephitis	Striped skunk
4,6,7,8	Lutra canadensis	River otter
1,5,9	Didelphis virginiana	Opossum
1,5	Dasypus novemcinctus	Armadillo
1,4,5,9	Oryzomys palustris	Marsh rice rate
1,4,5,9	Sigmodon hispidus	Cotton rat
1,3,4,5,6	Ondatra zibethicus	Muskrat
1,3,4,5,6,7,8,9	Procyon lotor	Raccoon
1	Sylvilagus aquaticus	Swamp rabbit
1	Myocastor coypus	Nutria
1	Odocoileus virginianus	White-tailed deer

Observed connections = 266
Possible connections = 700
Connectivity index = 38%

The 10 food types are:

(1)	aquatic plants	(6)	fish
(2)	worms	(7)	amphibians
(3)	mollusks	(8)	reptiles
(4)	crustaceans	(9)	birds
(5)	insects	(10)	mammals

Table 5A. Detailed List of Vertebrate Species Found in Forested Wetlands Surrounding Lake Pontchartrain, LA, During Summer. The Number Before Each Species Indicate Which of the 10 General Food Types Each is Known to Use

Food Types Used	Species: Scientific Name	Species: Common Name
Reptiles		
1,3,5,7,8	Macroclemys temmincki	Alligator snapping turtle
1,3,4,6,10	Alligator mississippiensis	American alligator
1,3,4,5,6	Sternotherus odoratus	Stinkpot
3,5	Kinosternon subrubrum	Mud turtle
5	Anolis carolinensis	Green anole
4,5	Scincella laterale	Ground skink
2,5,8,10	Eumeces fasciatus	Five-lined skink
5	E. laticeps	Broad-headed skink
6	Nerodia cyclopion	Green water snake
4,6,7	N. rhombifera	Diamondback water snake
4,6,7	N. erythrogaster	Red-bellied water snake
4,5,6,7	N. fasciata	Banded water snake
4	Regina grahamii	Graham's water snake
4	R. rigida	Glossy water snake
2,3,5,6,7,9,10	Thamnophis sirtalis	Common garter snake
5,6,7,10	T. proximus	Western garter snake
7	Farancia abacura	Mud snake
5,6,7,9,10	Coluber constrictor	Black racer
3,5,7	Opheodrys aestivus	Rough green snake
7,8,9,10	Elaphe obsoleta	Black rat snake
8,9,10	Lampropeltis getulus	Eastern king snake
8	Micrurus fulvius	Eastern coral snake
7,9,10	Agkistrodon contortrix	Copperhead
6,7,8,9,10	A. piscivorus	Cottonmouth moccasin
7,8,9,10	Crotalus horridus	Timber rattlesnake
1,2,3,4,5,6,8,9,10	Chelydra serpentina	Snapping turtle
1,2,3,4,5	Terrapene carolina	Box turtle
1,2,3,4,5,6	Chrysemys picta	Painted turtle
1,4,7	Deirochelys reticularia	Chicken turtle
1,4,5	Chrysemys scripta	Red-eared turtle
Birds		
2,4,5,6,7,8	Anhinga anhinga	Anhinga
4,5,6,7,8,9,10	Ardea herodias	Great blue heron
2,4,5,6,7,8,10	Butorides striatus	Striated green heron
4,5,6,7,8	Florida caerulea	Little blue heron

The 10 food types are:

(1) aquatic plants (2) worms (3) mollusks (4) crustaceans (5) insects (6) fish (7) amphibians (8) reptiles (9) birds (10) mammals

Table 5A. (Continued)

Food Types Used	Species Scientific Name	Common Name
Birds (Continued)		
1,3,4,5,6,7,8,10	*Casmerodius albus*	Common egret
3,4,5,6,7,8	*Egretta thula*	Snowy egret
2,3,4,5,6,7,8	*Hydranassa tricolor*	Louisiana heron
2,4,5,6	*Nycticorax nycticorax*	Black crowned night heron
3,4,6,8,9,10	*Nyctanassa violacea*	Yellow crowned night heron
2,3,4,5,6,7,8,10	*Ixobrychus exilis*	Least bittern
5,6,8	*Mycteria americana*	Wood ibis
3,4,5,8	*Eudocimus albus*	White ibis
1,2,3	*Porphyrula martinica*	Purple gallinule
1,5	*Aix sponsa*	Wood duck
5,7,8	*Elanoides forficatus*	Swallow-tailed kite
5,7,8	*Ictinia misisippiensis*	Mississippi kite
5,7,8,9,10	*Accipiter cooperi*	Cooper's hawk
2,3,5,7,8,9,10	*Buteo lineatus*	Red-shouldered hawk
2,4,5,7,8,9,10	*Buteo platypterus*	Broad-winged hawk
1,5	*Archilochus colubris*	Ruby-throated hummingbird
1,5	*Colaptes auratus*	Yellow-shafted flicker
1,5	*Dryocopus pileatus*	Pileated woodpecker
1,5,7	*Melanerpes carolinus*	Red-bellied woodpecker
1,5	*Picoides villosus*	Hairy woodpecker
1,5	*P. pubescens*	Downy woodpecker
1,5,7,8	*Coccyzus americanus*	Yellow-billed cuckoo
5,7,9,10	*Tyto alba*	Barn owl
2,3,4,5,6,7,8,9,10	*Otus asio*	Screech owl
4,5,6,7,8,9,10	*Bubo virginianus*	Great horned owl
3,5,6,7,8,9,10	*Strix varia*	Barred owl
5	*Chaetura pelagica*	Chimney swift
1,5	*Myiarchus crinitus*	Great crested flycatcher
1,5	*Empidonax virescens*	Acadian flycatcher
1,5	*Cantopus virens*	Eastern wood pewee
1,3,5,7,8	*Thryothorus ludovicianus*	Carolina wren
5	*Polioptila caerulea*	Blue-gray gnatcatcher
1,5	*Vireo griseus*	White-eyed vireo
1,5	*V. flavifrons*	Yellow-throated vireo
5	*Parula americana*	Parula warbler
5	*Dendroica dominica*	Yellow-throated warbler
5	*Limnothlypis swainsonii*	Swainson's warbler
3,5	*Protonotaria citrea*	Prothonotary warbler
1,5	*Geothlypis trichas*	Yellowthroat
1,5	*Oporonis formosus*	Kentucky warbler
5	*Wilsonia citrina*	Hooded warbler

The 10 food types are:

(1) aquatic plants (4) crustaceans (7) amphibians (10) mammals
(2) worms (5) insects (8) reptiles
(3) mollusks (6) fish (9) birds

Table 5A. (Continued)

Food Types Used	Species: Scientific Name	Species: Common Name
Birds (Continued)		
1,3,5,7,8,9,10	*Cyanocitta cristata*	Blue jay
1,3,4,5,8,9,10	*Corvus brachyrhynchos*	Common crow
1,4,6,9	*Corvus ossifragus*	Fish crow
1,5	*Parus carolinensis*	Carolina chickadee
1,3,5	*P. bicolor*	Tufted titmouse
1,2,3,4,5,7,8	*Toxostoma rufum*	Brown thrasher
1,2,5	*Hylocichla mustelina*	Wood thrush
1,5	*Vireo olivaceus*	Red-eyed vireo
1,5	*Agelaius phoeniceus*	Red-winged blackbird
1,2,3,4,5,6,7,8,9,10	*Quiscalus quiscula*	Common grackle
1,5	*Molothrus ater*	Brown-headed cowbird
1,3,5	*Piranga rubra*	Summer tanager
1,2,4,5,7,8	*Cardinalis cardinalis*	Cardinal
5	*Pipilo erythrophthalmus*	Rufous-sided towhee
Mammals		
5	*Myotis austroriparius*	Southeastern bat
5	*Lasiurus borealis*	Red bat
5	*L. seminolus*	Seminole bat
4,6,7,9,10	*Mustela vison*	Mink
4,5,7,10	*Mephitis mephitis*	Striped skunk
4,6,7,8	*Lutra canadensis*	River otter
9,10	*Lynx rufus*	Bobcat
1,5,9	*Didelphis virginianus*	Opossum
1,2,3,4,5,6,7,8,9,10	*Blarina brevicauda*	Short-tailed shrew
1,5	*Dasypus novemcinctus*	Armadillo
1,5	*Sylvilagus floridanus*	Cottontail rabbit
1,5	*Sciurus niger*	Fox squirrel
1,9	*Glaucomys volans*	Southern flying squirrel
1,4,5,9	*Oryzomys palustris*	Marsh rice rat
1,3,5	*Neotoma floridana*	Wood rat
1,3,4,5,6	*Ondatra zibethicus*	Muskrat
1	*Myocastor coypus*	Nutria
1,5,10	*Urocyon cinereoargenteus*	Gray fox
1,3,4,5,6,7,8,9	*Procyon lotor*	Raccoon
1	*Sylvilagus aquaticus*	Swamp rabbit
1	*Sciurus carolinensis*	Gray squirrel
1	*Peromyscus gossypinus*	Cotton mouse
1	*Odocoileus virginianus*	White-tailed deer

Observed connections = 403
Possible connections = 1120
Connectivity index = 36%

The 10 food types are:

(1) aquatic plants
(2) worms
(3) mollusks
(4) crustaceans
(5) insects
(6) fish
(7) amphibians
(8) reptiles
(9) birds
(10) mammals

Table 6A. Detailed List of Vertebrate Species Found in Forested Wetland Surrounding Lake Pontchartrain, LA, During Winter. The Number Before Each Species Indicate Which of the 10 General Food Types Each is Known to Use

Food Types Used	Species: Scientific Name	Species: Common Name
Birds		
4,5,6,7,8,9,10	*Ardea herodias*	Great blue heron
1,3,4,5,6,7,8,10	*Casmerodius albus*	Common egret
3,4,5,6,7,8	*Egretta thula*	Snowy egret
2,3,4,5,6,7,8	*Hydranassa tricolor*	Louisiana heron
3,4,5,6,7,8,10	*Botaurus lentiginosus*	American bittern
3,4,5,8	*Eudocimus albus*	White ibis
1,3,4,5,6	*Anas platyrhynchos*	Mallard
1,5	*Aix sponsa*	Wood duck
1,3,4,5,6,7	*Lophodytes cucullatus*	Hooded merganser
5,7,8,9,10	*Accipiter cooperi*	Cooper's hawk
2,3,5,7,8,9,10	*Buteo lineatus*	Red-shouldered hawk
1,2,3,4,5,7	*Rallus elegans*	King rail
2,3,5	*Philohela minor*	American woodcock
5,7,9,10	*Tyto alba*	Barn owl
2,3,4,5,6,7,8,9,10	*Otus asio*	Screech owl
4,5,6,7,8,9,10	*Bubo virginianus*	Great horned owl
3,5,6,7,8,9,10	*Strix varia*	Barred owl
1,3,4,5,6,7,8,9,10	*Megaceryle alcyon*	Belted kingfisher
1,5	*Colaptes auratus*	Yellow shafted flicker
1,5	*Dryocopus pileatus*	Pileated woodpecker
1,5,7	*Melanerpes carolinus*	Red-bellied woodpecker
1,5	*Sphyrapicus varius*	Yellow-bellied sapsucker
1,5	*Picoides villosus*	Hairy woodpecker
1,5	*P. pubescens*	Downy woodpecker
5	*Certhia familiaris*	Brown creeper
1,3,4,5	*Troglodytes aedon*	House wren
5	*T. troglodytes*	Winter wren
1,3,5,7,8	*Thryothorus ludovicianus*	Carolina wren
5	*Regulus satrapa*	Golden-crowned kinglet
1,5	*R. calendula*	Ruby-crowned kinglet
1,3,5	*Porzana carolina*	Sora
1,5	*Sayornis phoebe*	Eastern phoebe
1,3,5,7,8,9,10	*Cyanocitta cristata*	Blue jay
1,3,4,5,8,9,10	*Corvus brachyrhynchos*	Common crow
1,4,6,9	*C. ossifragus*	Fish crow

The 10 food types are:

(1) aquatic plants	(4) crustaceans	(7) amphibians	(10) mammals
(2) worms	(5) insects	(8) reptiles	
(3) mollusks	(6) fish	(9) birds	

Table 6A. (Continued)

Food Types Used	Species: Scientific Name	Species: Common Name
Birds (Continued)		
1,5	Parus carolinensis	Carolina chickadee
1,3,5	P. bicolor	Tufted titmouse
1,2,3,4,5,7,8	Toxostoma rufum	Brown thrasher
1,2,3,5	Turdus migratorius	Robin
1	Catharus guttatus	Hermit thrush
1,5	Bombycilla cedorum	Cedar waxwing
1,5	Vireo solitarius	Solitary vireo
1,5	Vermivora celata	Orange-crowned warbler
1,5	Dendroica coronata	Myrtle warbler
1,5	Agelaius phoeniceus	Red-winged blackbird
1,3,4,5,6,7	Euphagus carolinus	Rusty blackbird
1,2,3,4,5,6,7,8,9,10	Quiscalus quiscula	Common grackle
1,5	Molothrus ater	Brown-headed cowbird
1,3,5	Cardinalis cardinalis	Cardinal
1,2,4,5,7,8	Pipilo erythropthalmus	Rufous-sided towhee
1,5	Melospiza lincolnii	Lincoln's sparrow
1,5	M. georgiana	Swamp sparrow
1,5	M. melodia	Song sparrow
1	Carpodacus purpureus	Purple finch
1,5	Carduelis tristis	American goldfinch
1,5	Zonotrichia albicollis	White-throated sparrow
Mammals		
4,6,7,9,10	Mustela vison	Mink
4,5,7,10	Mephitis mephitis	Striped skunk
4,6,7,8	Lutra canadensis	River otter
9,10	Lynx rufus	Bobcat
1,5,9	Didelphis virginiana	Opossum
1,2,3,4,5,6,7,8,9,10	Blarina brevicauda	Short-tailed shrew
1,5	Dasypus novemcinctus	Armadillo
1,5	Sylvilagus floridanus	Cottontail rabbit
1,5	Sciurus niger	Fox squirrel
1,9	Glaucomys volans	Southern flying squirrel
1,4,5,9	Oryzomys palustris	Marsh rice rat
1,3,5	Neotoma floridana	Wood rat
1,3,4,5,6	Ondatra zibethicus	Muskrat
1,5,10	Urocyon cinereoargenteus	Gray fox
1,3,4,5,6,7,8,9	Procyon lotor	Raccoon

The 10 food types are:

(1) aquatic plants (4) crustaceans (7) amphibians (10) mammals
(2) worms (5) insects (8) reptiles
(3) mollusks (6) fish (9) birds

Table 6A. (Continued)

Food Types Used	Species Scientific Name	Common Name
Mammals (Continued)		
1	*Sylvilagus aquaticus*	Swamp rabbit
1	*Sciurus carolinensis*	Gray squirrel
1	*Peromyscus gossypinus*	Cotton mouse
1	*Myocastor coypus*	Nutria
1	*Odocoileus virginianus*	White-tailed deer

Observed connections = 296
Possible connections = 760
Connectivity index = 40%

The 10 food types are:

(1)	aquatic plants	(4)	crustaceans	(7)	amphibians	(10)	mammals
(2)	worms	(5)	insects	(8)	reptiles		
(3)	mollusks	(6)	fish	(9)	birds		

Marsh grass and pelican

Chapter 18

RECENT LAND USE CHANGES IN THE LAKE PONTCHARTRAIN WATERSHED

by

R. Eugene Turner
and
Judith R. Bond

ABSTRACT

This chapter describes recent changes in land use within the Lake Pontchartrain watershed. Locally important increases in the lake surface area are claiming a relatively small area of land. Forest area is still decreasing, although 60% of the original forested area remains; the volume and species composition has not stabilized because softwoods are replacing hardwood on the formerly virgin and second-growth stands. The area of field crops has remained fairly constant since the 1920's, but the area of pasture is still increasing. Urban areas now occupy about 6% of the total land surface. Freshwater runoff and nutrient loading to Lake Pontchartrain have probably increased recently as a result.

INTRODUCTION

Lake Pontchartrain is part of a larger drainage system we have called that Lake Pontchartrain Watershed (LPW) (Fig. 1). Land use changes within the watershed may have an impact on the ecology of Lake Pontchartrain through changes in the quality and quantity of runoff entering the lake and through changes in the hydrology of the basin. It is the purpose of this report to briefly document recent land use changes in the LPW with the use of figures and maps.

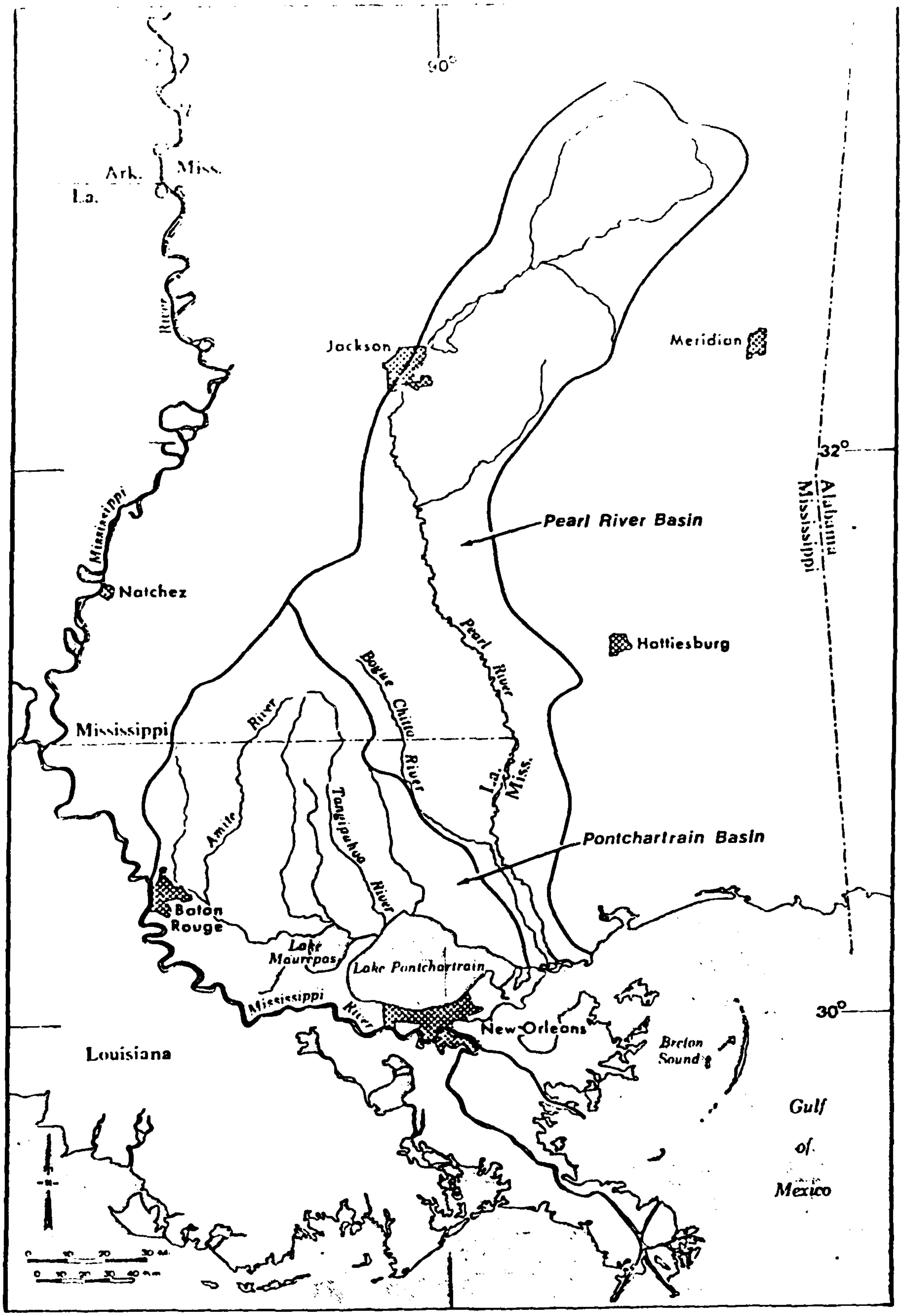

Figure 1. A general area map of the Lake Pontchartrain Basin showing the major rivers, cities, and the adjoining Pearl River Basin.

MATERIALS AND METHODS

I. Forests

The area and content of Louisiana and Mississippi forests were surveyed by the U.S. Forest Service in the 1930's and at ten-year intervals beginning in 1953-1954 (U.S. Forest Service 1945, 1955, 1973, and 1978; Sternitzke 1965; Corty and Main 1974; Earles 1975). These reports contain data on acreage, volume, and species composition for the state and region, often by counties and parishes. The Southeast Forest Region of the U.S. Forest Service is comprised of seven parishes within the LPW: Washington, St. Tammany, Tangipahoa, St. Helena, Livingston, East Feliciana, and East Baton Rouge (Fig. 2). Although this region is not the entire LPW and even includes some land outside it, the U.S. Forest Service data were collected in a systematic and similar manner since the 1930's and are included for analysis in this paper.

We determined land use and vegetation types by using Lockett's 1872 map (1874), Hilgard's map (1884), soil maps (Lytle and Sturgis 1962), and U.S. Forest Service maps (1955, 1958).

II. Agricultural and Urban Areas

The Louisiana Tax Commission has published biennial reports of land use inventories since 1907. These were consulted to determine the relative changes in agricultural land areas from 1921 to 1975. Other land use patterns were compiled from a 1975 Louisiana State Planning Office report. The latter is an accurate representation of actual land use derived from a variety of aerial photo-interpretative techniques; the tax-surveys often had missing acreages (up to 10% of the total acreage in the parish) and may have relied on subjective interpretations of what land was taxed and in what category.

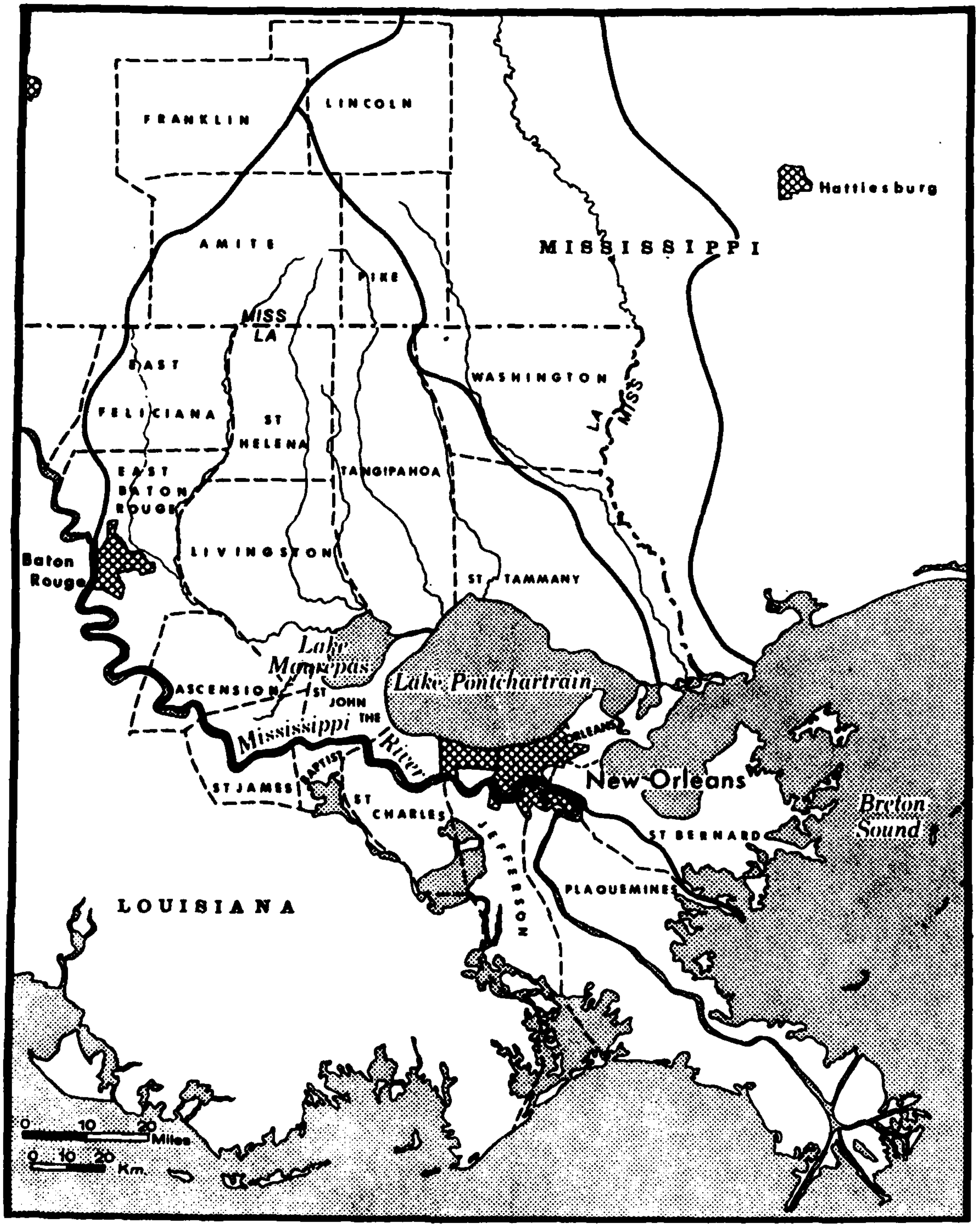

Figure 2. The parishes and counties of the Lake Pontchartrain Watershed.

Changes in the area of agricultural lands in the LPW for the seven major parishes of the area (St. Tammany, Tangipahoa, St. Helena, Livingston, East Baton Rouge, East Feliciana, and Ascension, Fig. 2) are discussed below.

III. Other Sources

Saucier's (1963) paleogeographic reconstruction of Lakes Maurepas and Pontchartrain was used to estimate the increase in lake surface from 3750 BP (before the present) to 1963.

IV. Brief Description of the Study Area

The Lake Pontchartrain watershed (LPW) is a lowland coastal area located in southeastern Louisiana. One-fifth of the total area is Lake Pontchartrain and the smaller Lake Maurepas (Fig. 3). Above the 1.5 m (5 ft) contour is the Pleistocene terrace; below this is mostly prairie alluvium. The Mississippi River is presently the western border, but it previously crisscrossed the area, as evidenced by the remnants of the deltaic tributary network. Saucier's (1963) monograph is an excellent summary of the recent geomorphology of the prairie region. Craig et al. (1979) described the rates and implications of coastal wetland losses in the region. As a result of human interference with sediment supply and the natural hydrology, wetland subsidence and erosion presently exceed sediment accretion and land building.

The humid subtropical climate encourages a luxuriant fauna and flora. Le Page du Pratz, an early European colonialist of the 1700's, encountered now-absent buffalo and wapiti and described an incredibly rich wildlife (Le Page du Pratz 1774). But even in 1726 he complained of the soaring price of cypress lumber. The area was claimed by numerous

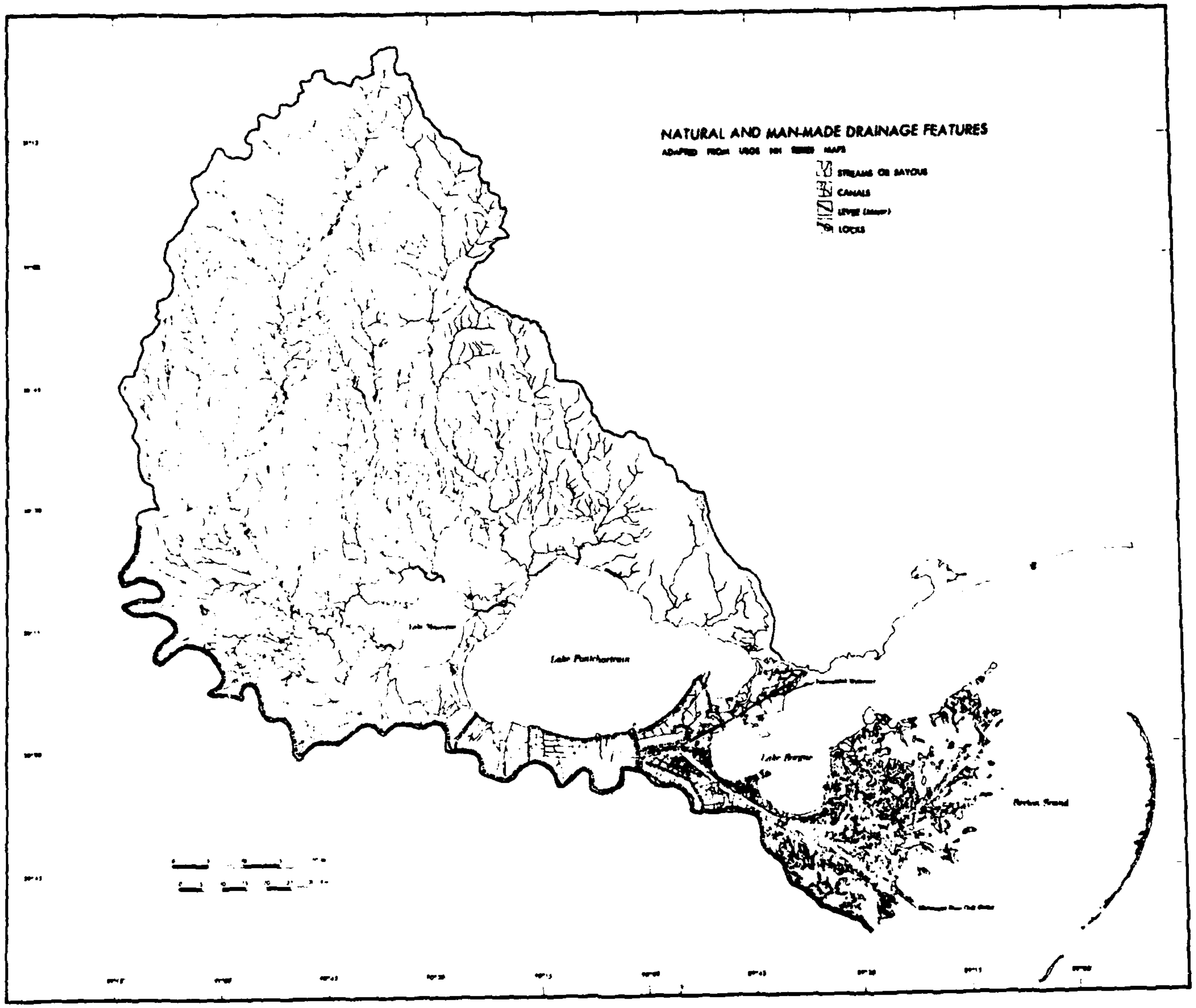

Figure 3. The natural and man-made drainage features of the Lake Pontchartrain Watershed.

European countries, and the colonial towns became the present major cities. Lumber, plantation, agricultural products, trade, and the seafood industry are the predominate business activities. The second and fifth largest seaports in the U.S. are in the watershed. Railroads, waterways, and highways have served as corridors for economic growth and settlement. In 1900, the population density of the state was 30 per $mile^2$ (2.6 per km^2); 23% was rural. In the 1970's it climbed to 81 mi^2 (2.6 km^2); 30% is rural. Thirty percent of the total population is presently settled in the two largest cities, New Orleans and Baton Rouge.

RESULTS

The natural drainage features of the basin are shown in Figure 3 along with the man-made features, which include navigation channels and canals. The latter features are easily recognized as the straight water courses, mostly along the Mississippi River and near New Orleans.

The lake surface area has been increasing steadily since the initial rise in sea level (Fig. 4). The prairie alluvium, deposited below the Pleistocene terrace of the northern half of the basin, has been eroding at the rate of about 15 ha annually for the last 3750 years. This is an obvious problem for those persons inhabiting the shoreline, but it is an insignificant change in land use relative to the total area of the LPW.

Most of the original vegetation at the time of European colonialization was forest (Fig. 5). The areas near the western shore of Lakes Maurepas and Pontchartrain were lowlands that were physiographically similar to the region of overbank southern riparian forests along the Mississippi River. Pine softwoods dominated the remaining northern portion of the basin, except along rivers. The largest decrease in

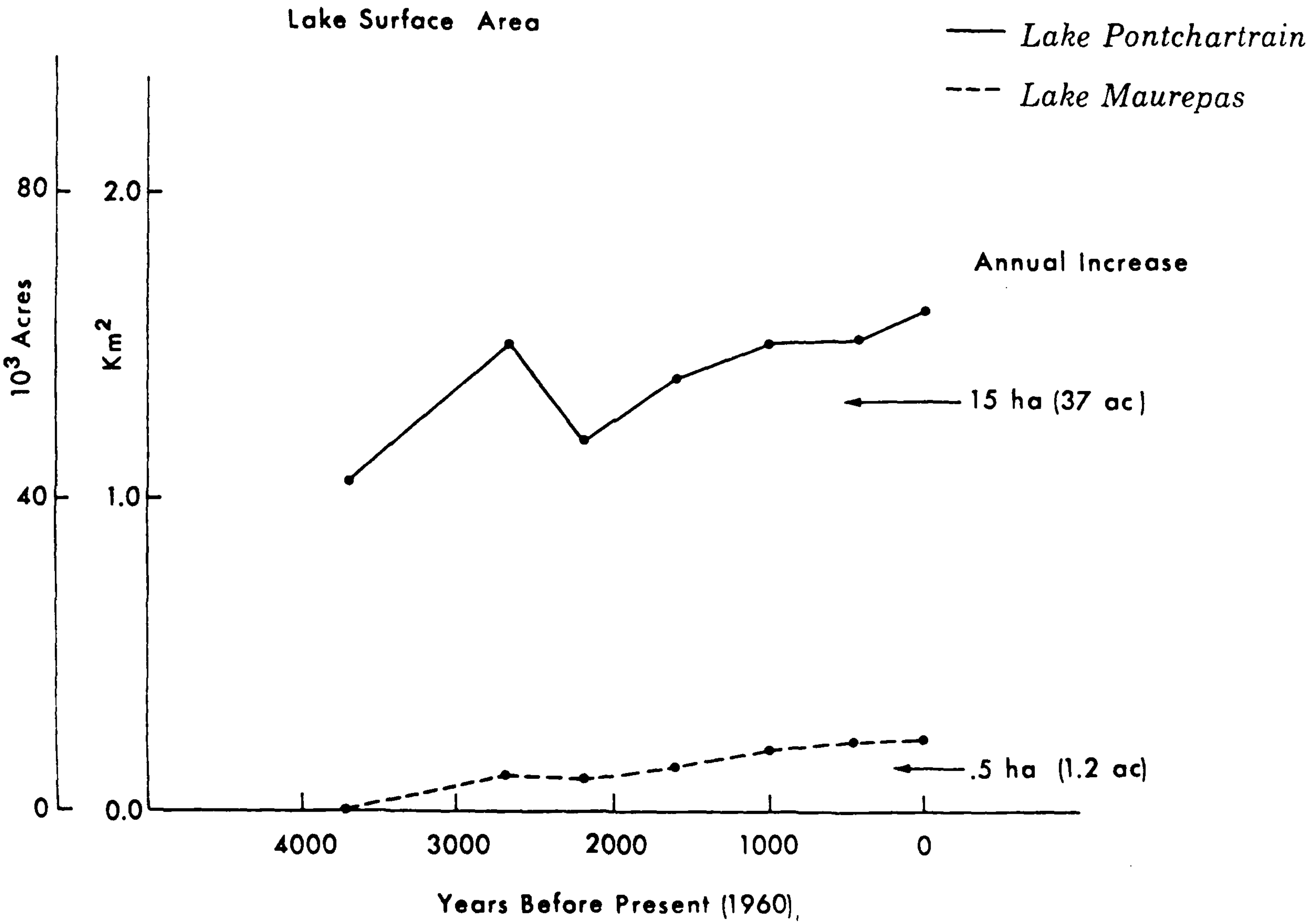

Figure 4. The lake surface area of Lakes Maurepas and Pontchartrain for the last 3750 years.

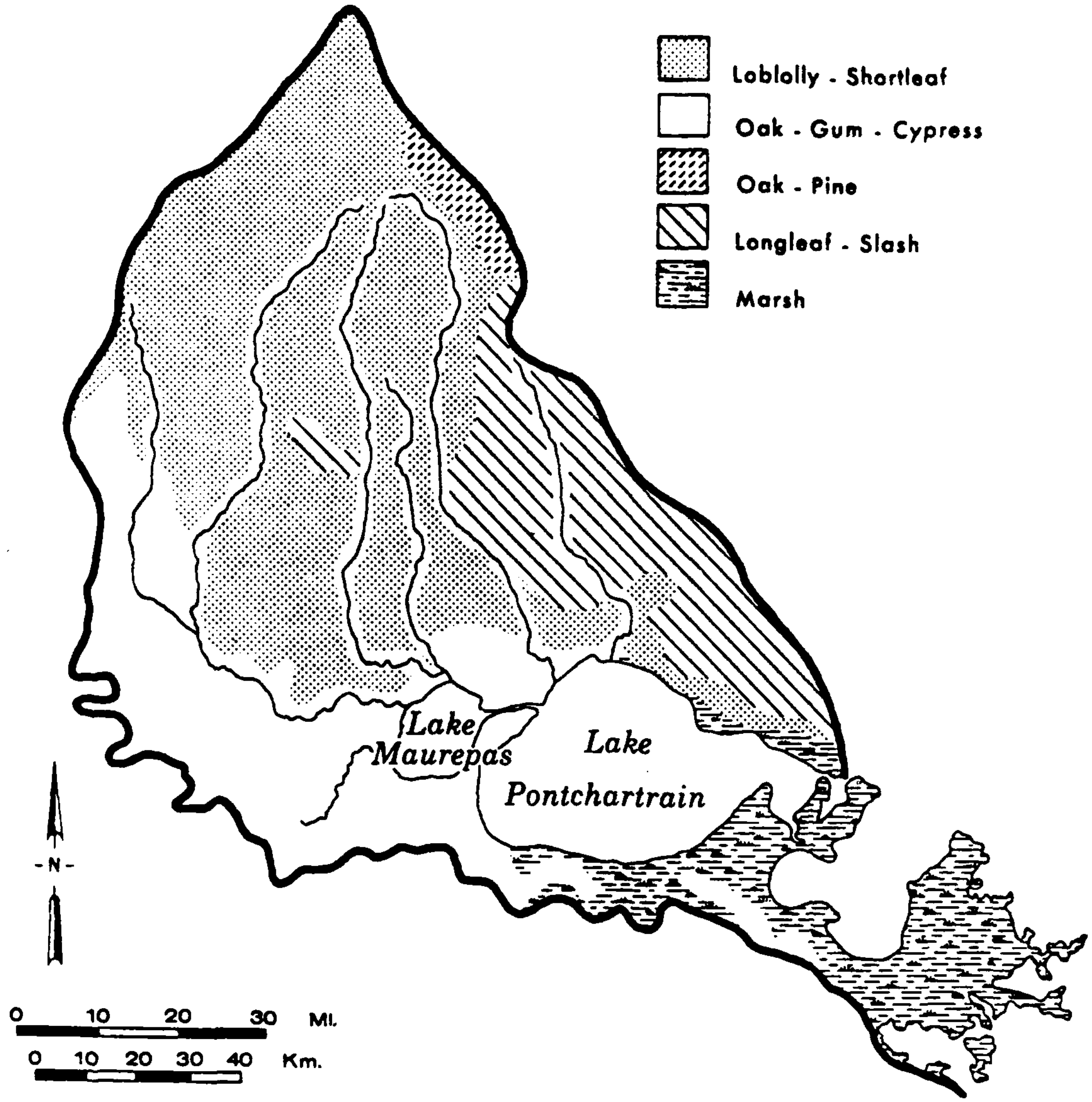

Figure 5. The major vegetation zones around 1700.

forested land areas since the 1700's has been in land formerly characterized by long-leaf slash pine vegetation; the largest gain in area has been by oak-pine and oak hardwood forest (Fig. 6). The total volume of growing stock has increased from the 1930's to the present (Fig. 7), but hardwoods are being replaced by pines--or at least are being stocked faster. The ratio of hardwood to softwood timber volume has been decreasing recently (Fig. 8). Much land, though classified as forested, is often thinly stocked. The present volume per acre is considerably less dense than in the 1700's and is often so reduced that satellite imagery interpretations suggest that many former swamps (wetlands with trees) are now functionally marshes (wetlands without trees). This is especially evident around the northwest shore of Lake Pontchartrain.

Land use vegetation in 1954 and 1972 is shown in Figures 9 and 10. Much of the land in the eastern portion of the LPW has been reforested since 1954, whereas agricultural area has increased dramatically near and between Baton Rouge and New Orleans (about 3 times higher). An examination of these same figures indicates that the urban areas have increased rapidly in the same period, particularly within the immediate vicinity of the lake.

The total area of agricultural lands has increased steadily in recent years (Fig. 11). However, most of this increase has been caused by a change in the area of pasture rather than by row crops.

An estimate of the present land use within the LPW is given in Table 1. Urban areas occupy about 6% of the total surface areas; agricultural lands, 22%; and forested areas, about 50% (upland and swamp). Sixteen percent of the area is wetlands.

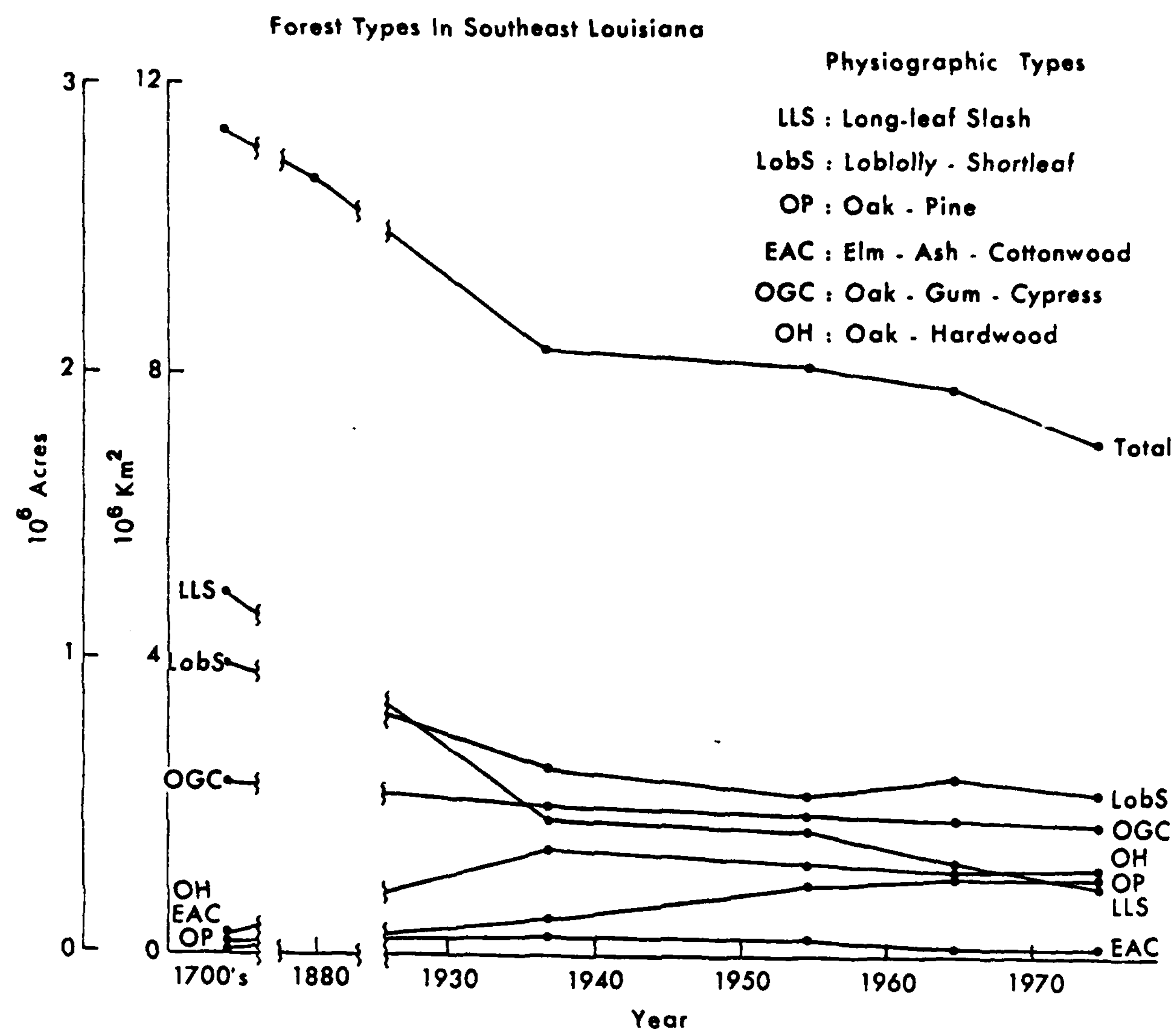

Figure 6. Forest types in southeast Louisiana from the time of the first arrival of European colonists to the present.

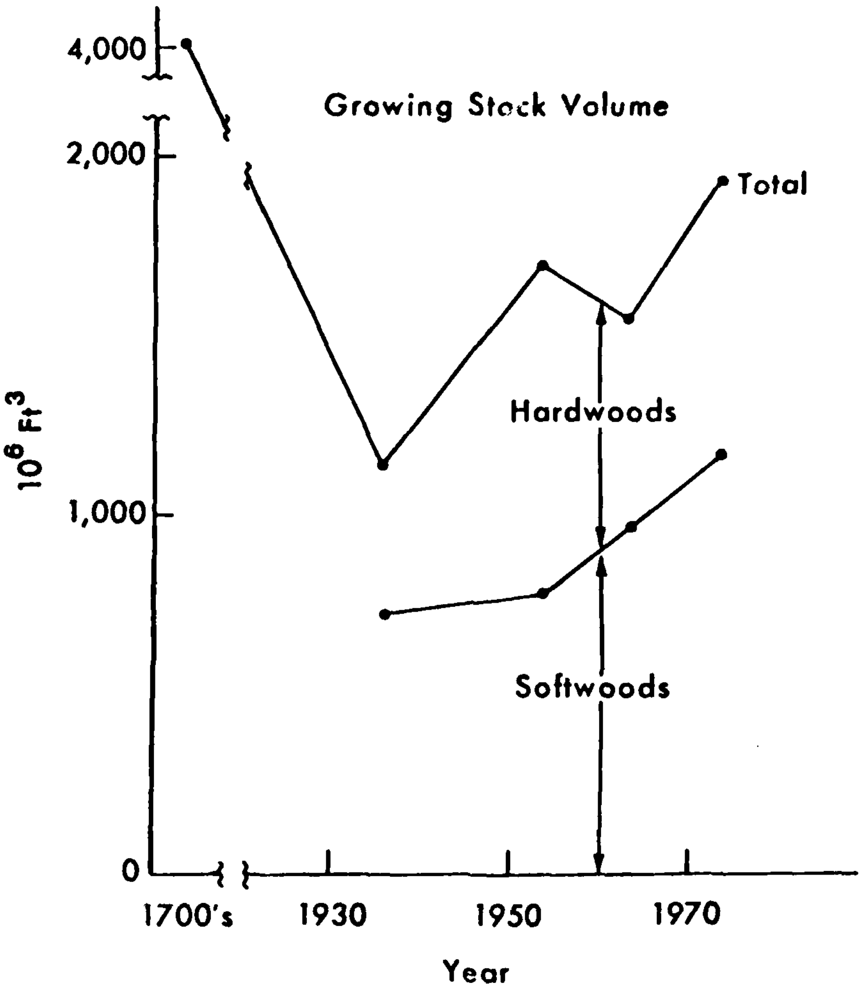

Figure 7. The growing stock volume in the Lake Pontchartrain Watershed in recent times.

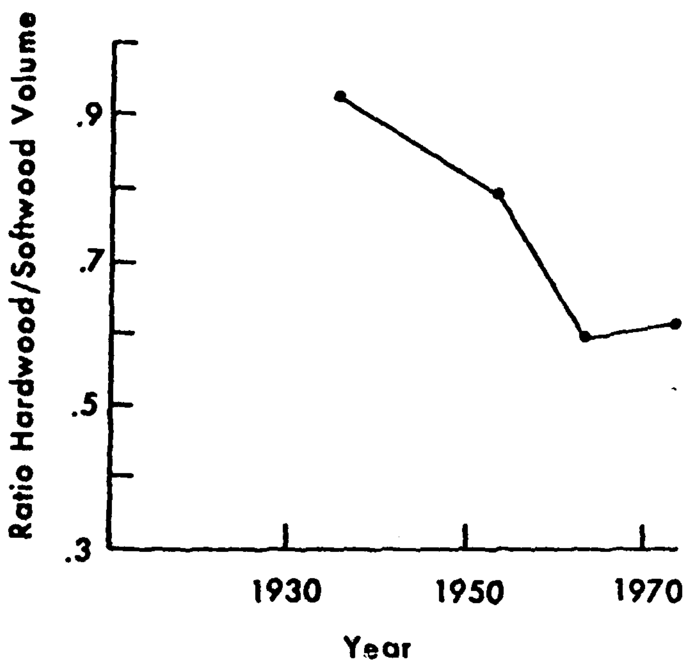

Figure 8. The changes in the hardwood: softwood growing volume of timber from 1935 to 1975 in the Lake Pontchartrain Watershed.

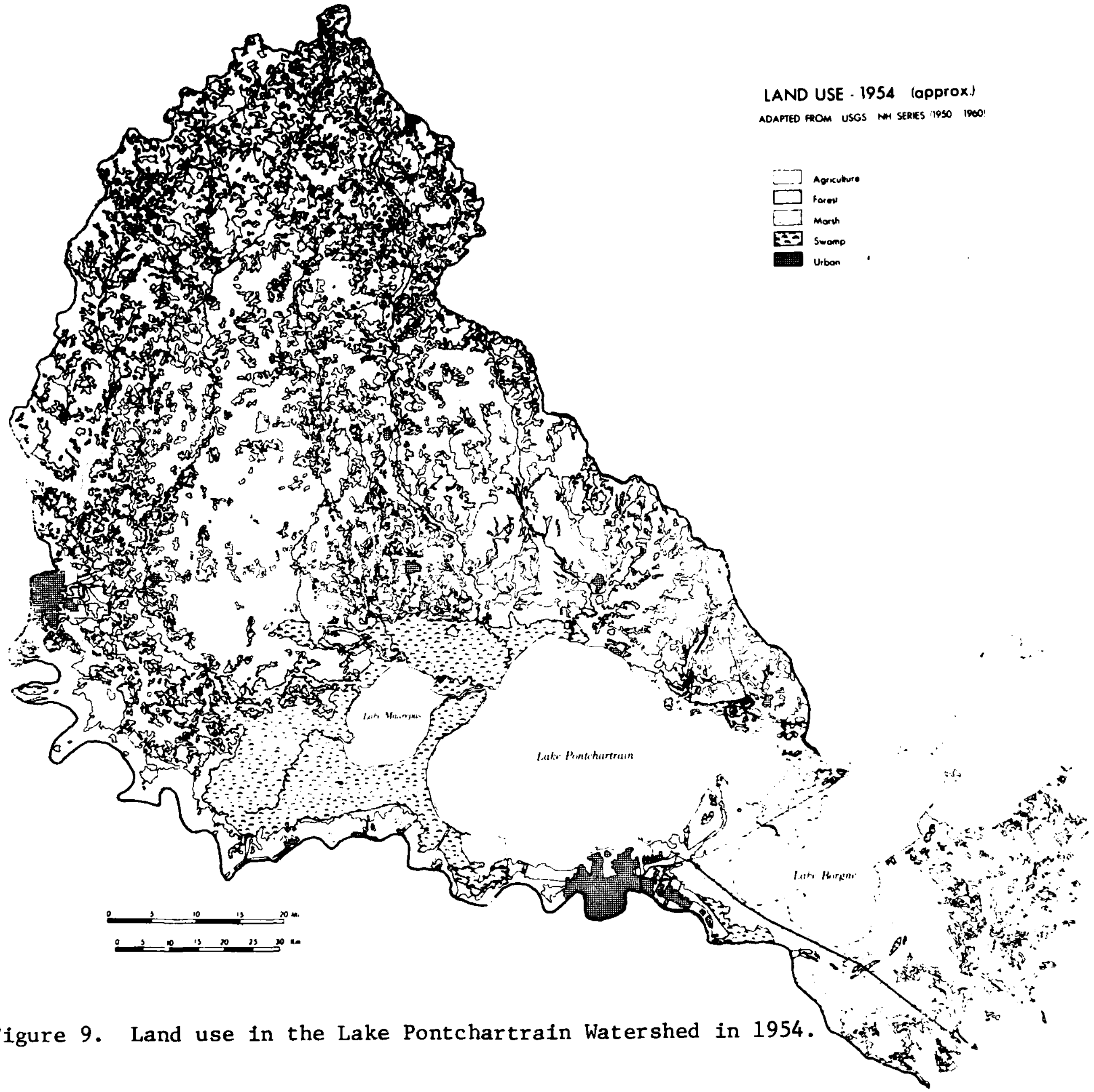

Figure 9. Land use in the Lake Pontchartrain Watershed in 1954.

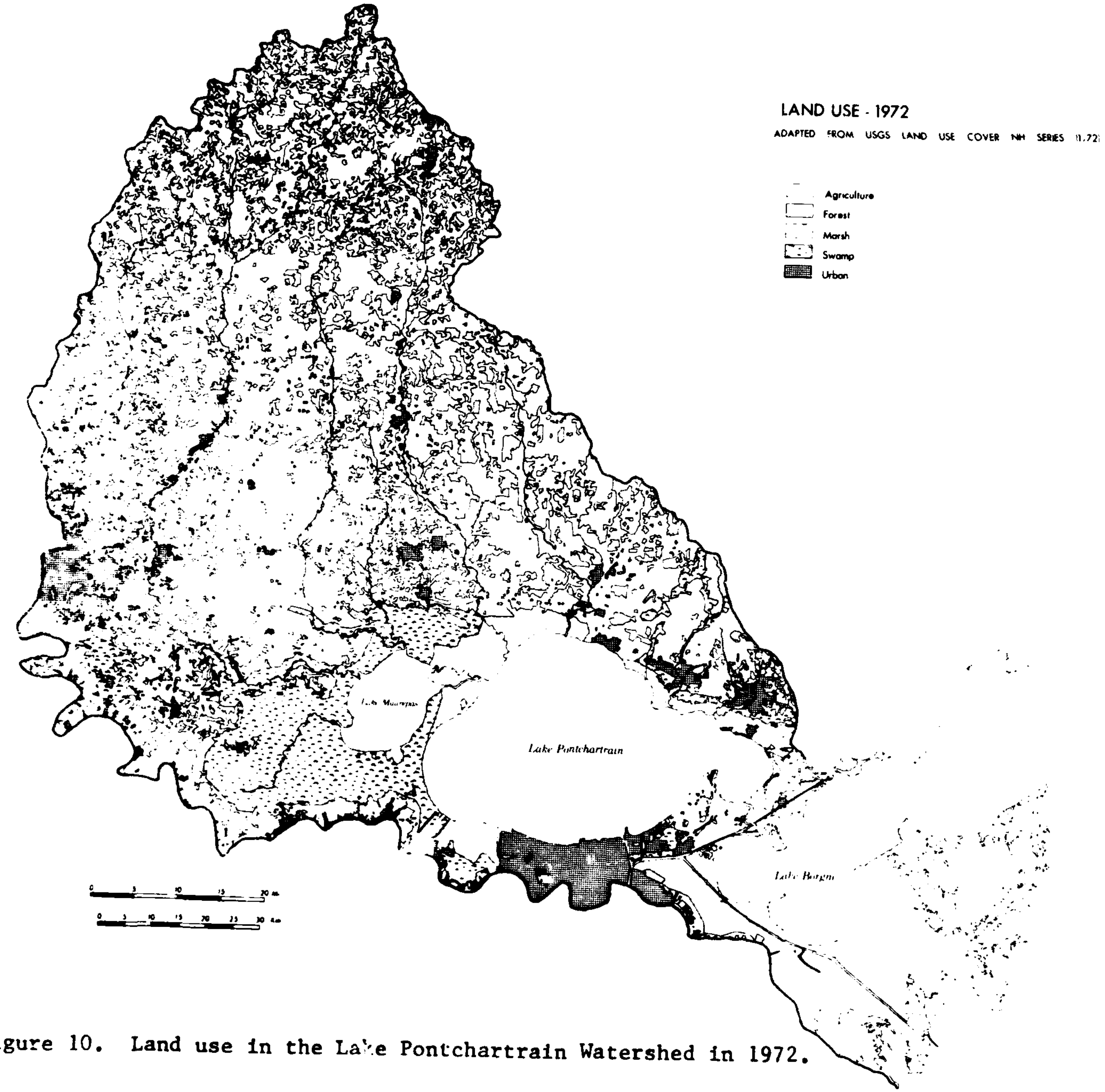

Figure 10. Land use in the Lake Pontchartrain Watershed in 1972.

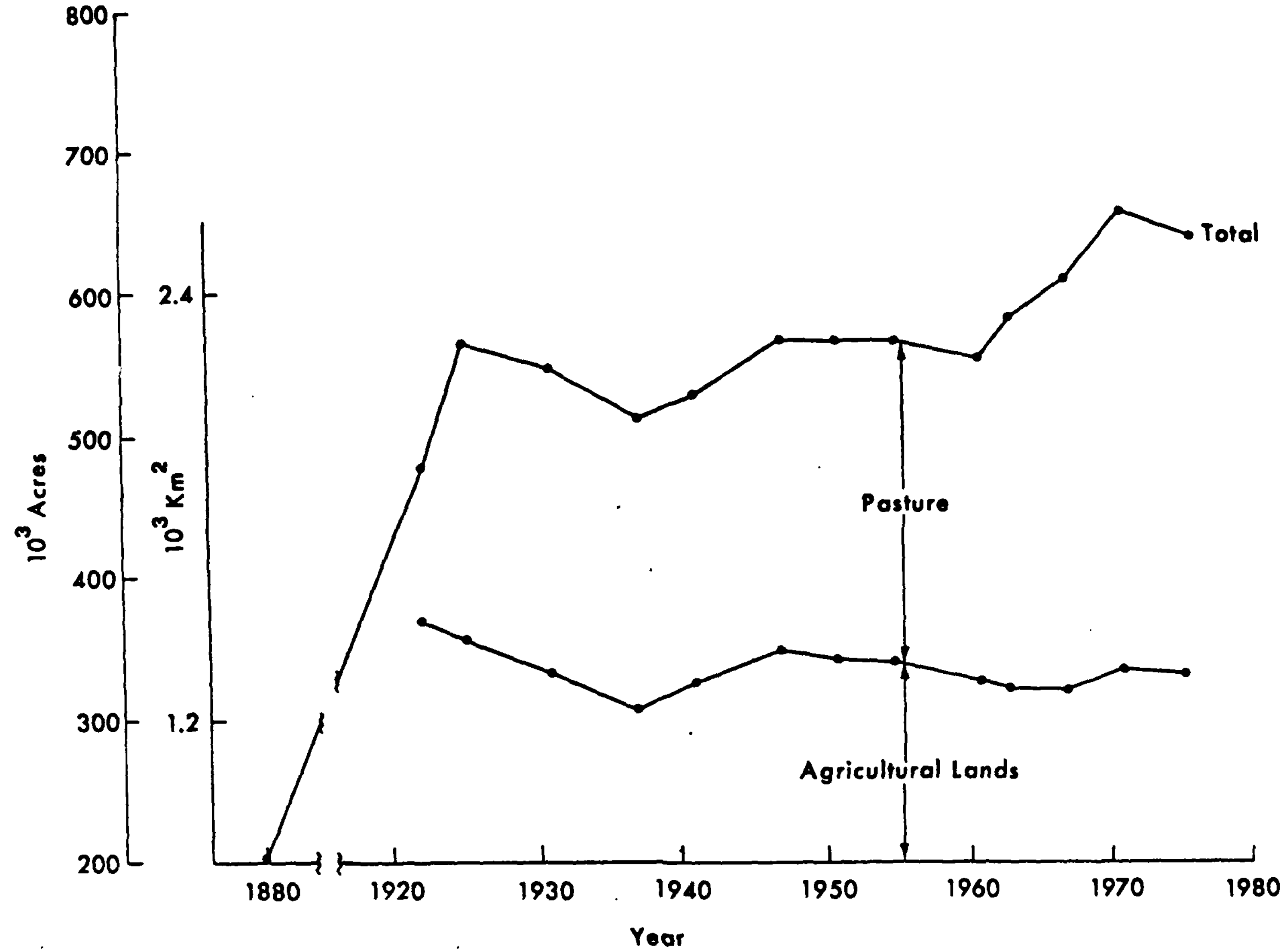

Figure 11. Agricultural land in the Lake Pontchartrain Watershed from 1880 to 1976 as based on the tax records for the major parishes.

Table 1. Present Land Use in Parishes and Counties of the Lake Pontchartrain Watershed (10^3 acres $\simeq 4 \times 10^6$ km^2)

	Urban and developed land	Agriculture	Upland forest	Wetland		Total land including water surface
				Swamp	Marsh	
Parish (LA)						
Ascension	8.4	91.4	35.1	50.4	1.7	192.4
East Baton Rouge	56.6	131.9	92.9	5.7	1.7	295.9
East Feliciana	3.5	126.7	153.7	0	0	284.8
Jefferson	91.4	3.7	3.7	26.4	81.3	584.4
Livingston	8.9	50.3	280.1	66.2	0	438.2
St. Helena	2.0	54.4	206.4	0	0	263.0
St. John the Baptist	4.2	27.9	4.4	81.5	17.5	238.0
St. Tammany	33.3	94.1	249.7	122.3	57.0	705.9
Tangipahoa	12.1	167	254.7	28.4	39.5	529.1
Washington	12.6	121.2	273.2	18.8	1.0	428.1
Percent	6%	22%	40%	10%	6%	100%
County (MS)						
Amite		147.4	280.0	39.2	0	466.6
Pike		125.5	108.0	28.8	0	262.4

DISCUSSION

Over the years, considerable land use changes have occurred in the LPW. Forest area has decreased, forest species have changed, and agricultural and urban lands have increased.

A major consideration is the change in the hydrology of the basin. It is well established that the quantity of runoff is indirectly dependent on the quantity of standing vegetation within the watershed (e.g., Branson 1975). When forests are cut, and agriculture areas or urbanization increases, then the water yield increases. The amount of increase depends on many factors including ground slope, soil type, and vegetation. Increases of 25% following forest clear-cutting are not unusual (Gray 1970). About 35 percent of the LPW is deforested; the remainder has less vegetation per area than when New Orleans first became a colonial city. Thus, the freshwater flow to Lake Pontchartrain is probably higher now than 100 years ago. Though the impact is ameliorated by the higher evapotranspiration of the replanted pines compared to the original hardwoods (Swank and Douglass 1974), the net result is a less saline lake (if the assumption is made that all other factors remain constant, including rainfall and tidal pass exchange).

Increased runoff, whether caused by devegetation, canals, channelization, or urban expansion, has secondary effects: (1) sedimentation losses increase in proportion to runoff (Ursic and Dendy 1965; Eckholm 1976) and have contributed to the decline of many western civilizations; (2) land use can be correlated with nutrient concentrations in streams (Omernik 1977); (3) urbanization, in particular, results in a significant concentration of many small quantities of pollutants (Whipple et al. 1978); and (4) it may take a long time for soil fertility to return to

its former condition following the effects of faster runoff (Marks and Bormann 1972). The net result is that nutrient loading to Lake Pontchartrain has probably increased at the expense of nutrients in the soil. The impact on Lake Pontchartrain can be documented in the response by the phytoplankton community; e.g., increased biomass, higher simulation ratios, and altered physiology (Dow and Turner, Chapter 7 and Stone et al., Chapter 8).

Levees, canals, pavement, biocides, navigation channels, and general ecosystem exploitation are results of 20th century human habitation of coastal Louisiana. The subtleties of their influence have been discussed in many symposia (e.g., Day et al. 1979), and they inhibit simplistic efforts to relate specific land use changes to specific impacts.

Crab traps and makeshift shelter in an old school bus

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APPENDIX

LAND USE AND VEGETATION MAPS

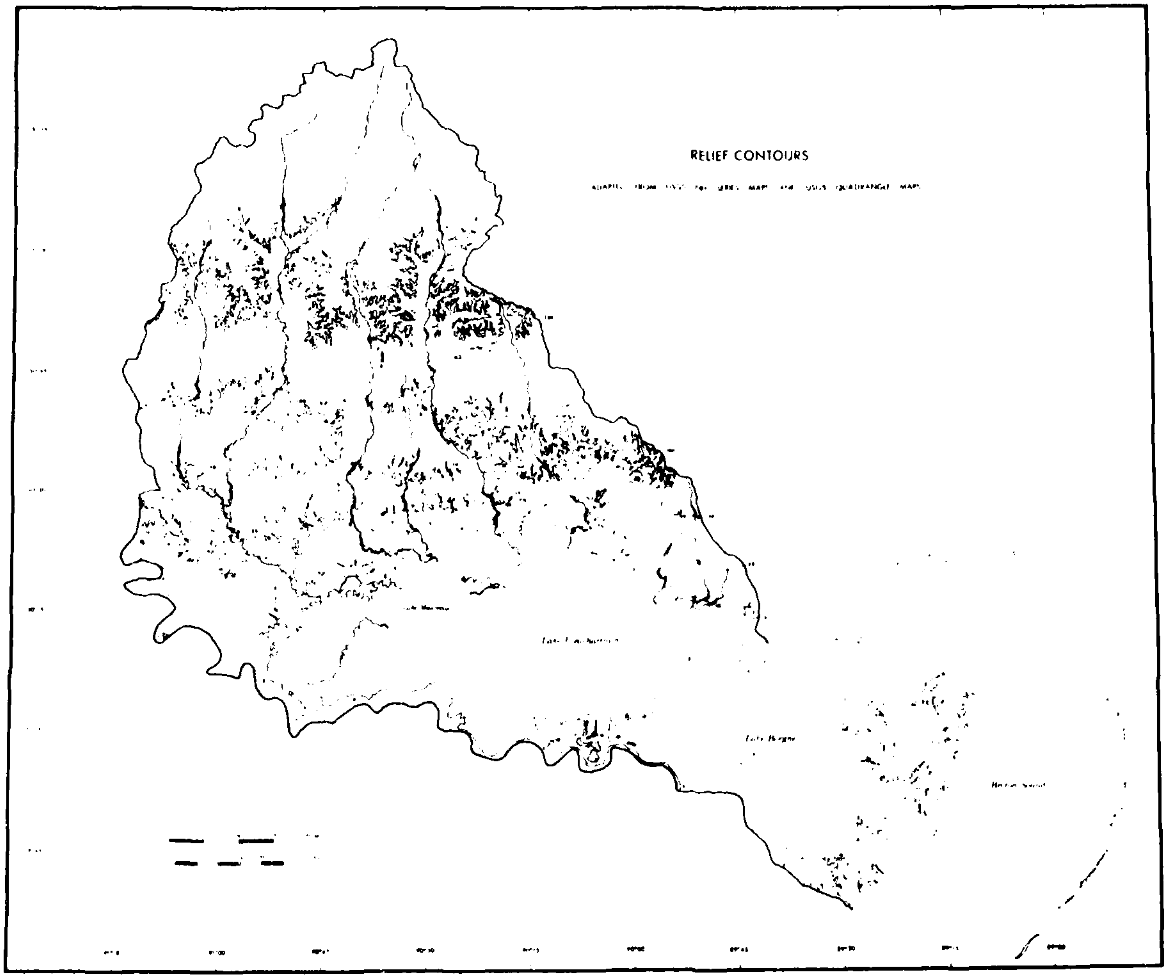

Figure 1A. The topographic relief of the Lake Pontchartrain Watershed with 5, 25, 50, 100, and 250 foot contours.

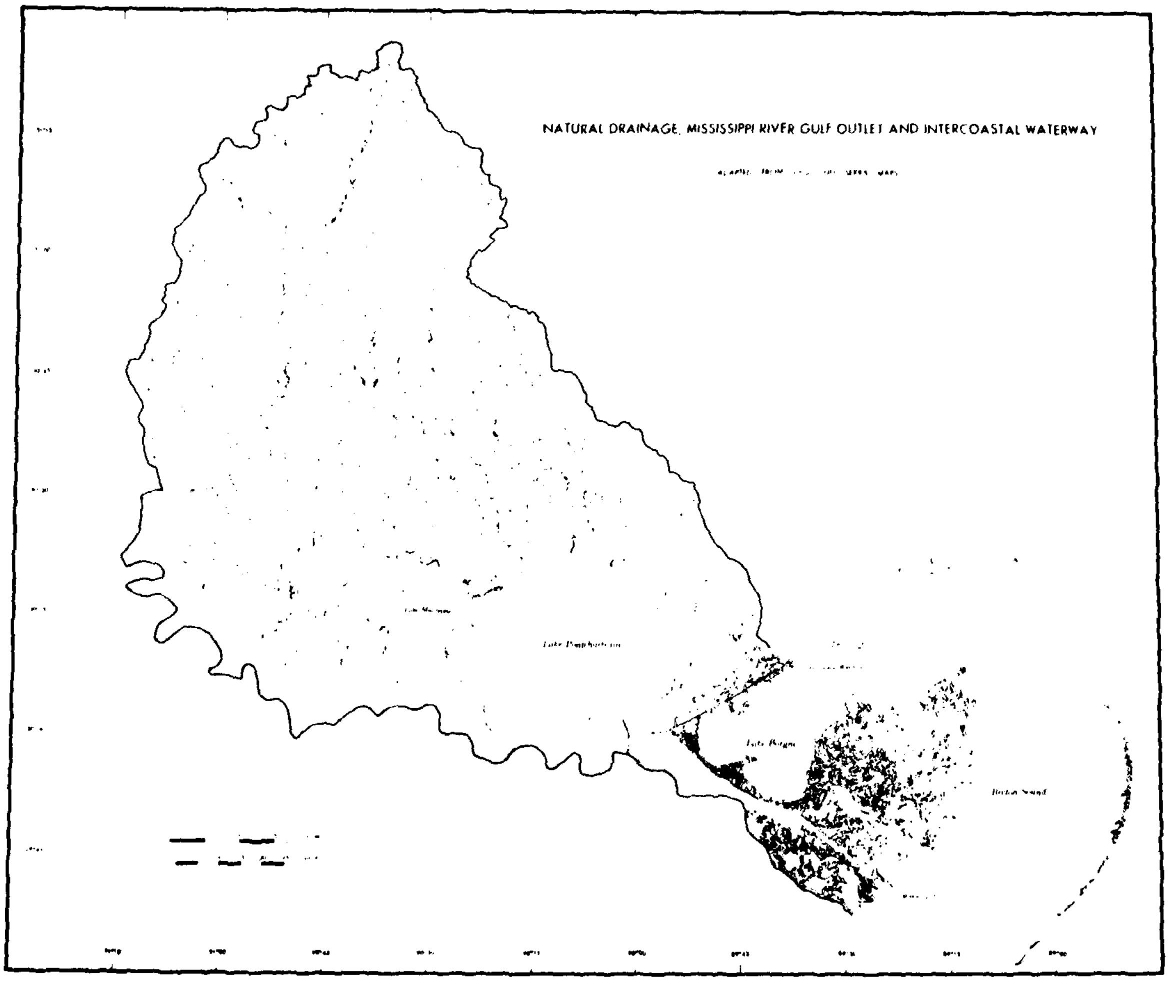

Figure 2A. The major natural drainage features, the Mississippi River Gulf Outlet and the Intercoastal Waterway of the Lake Pontchartrain Watershed.

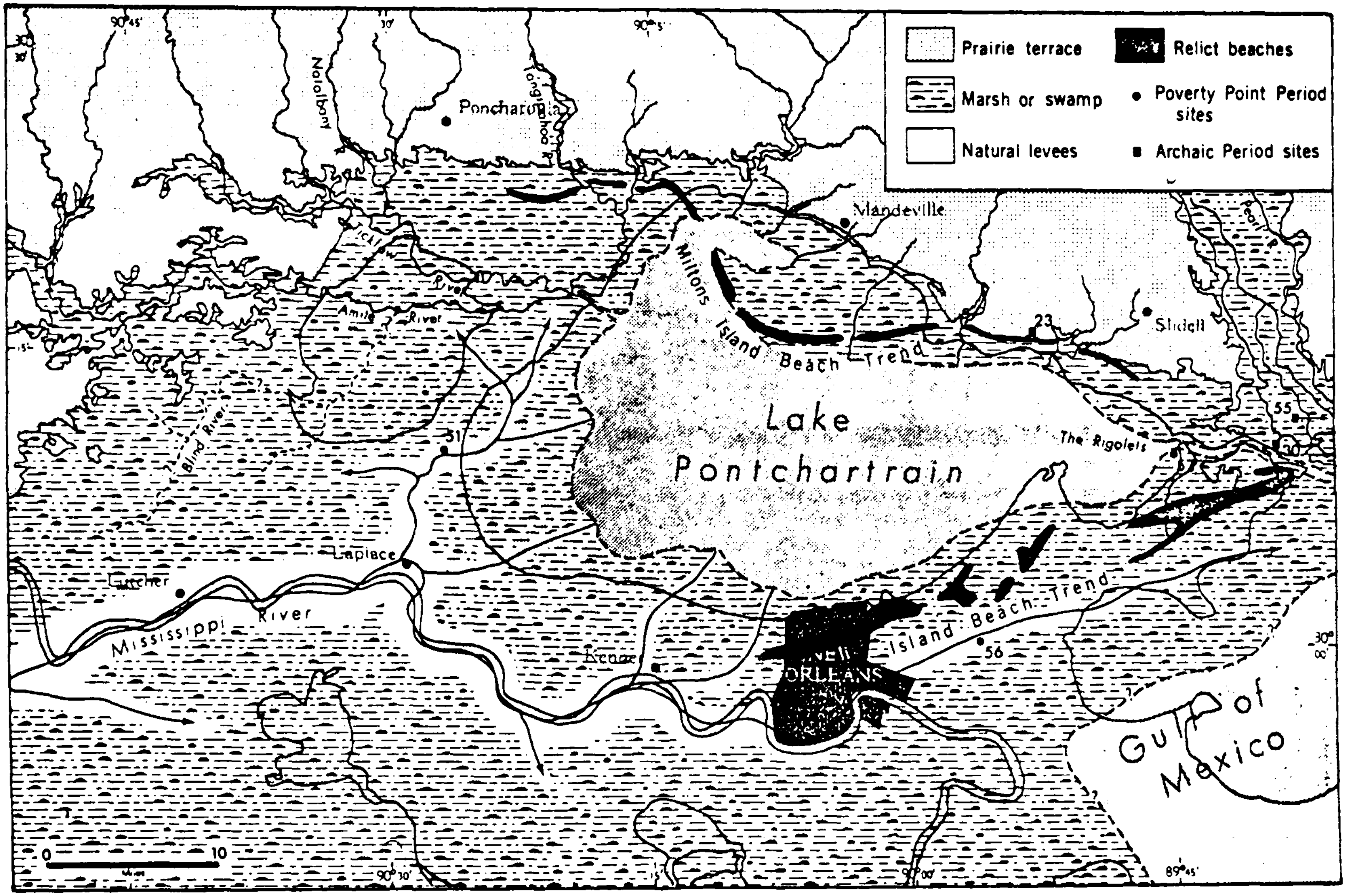

Figure 3A. The paleogeography of the Lake Pontchartrain area about 3500 to 4000 years ago (from Saucier 1963).

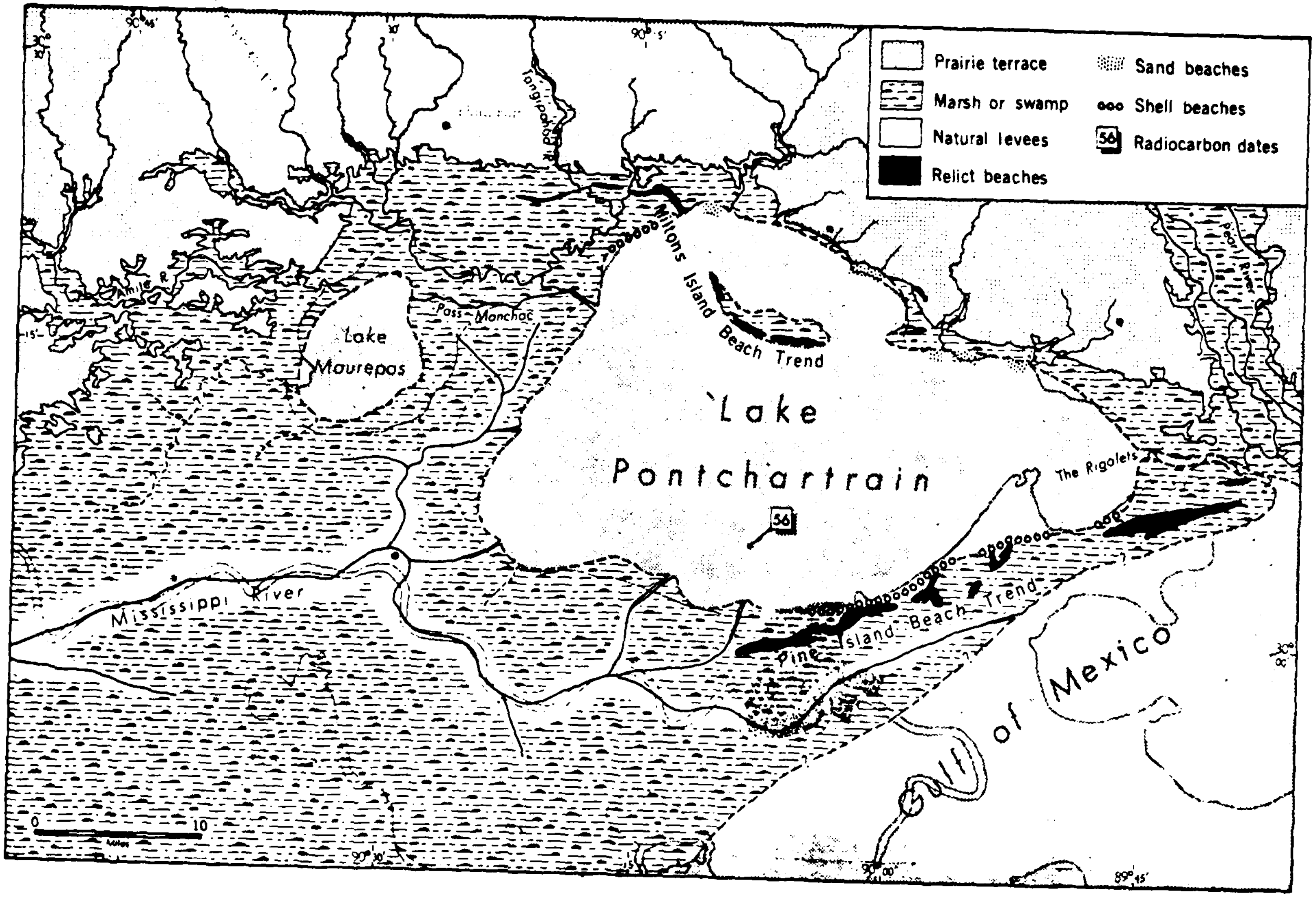

Figure 4A. The paleogeography of the Lake Pontchartrain area about 2600 to 2800 years ago (from Saucier 1963).

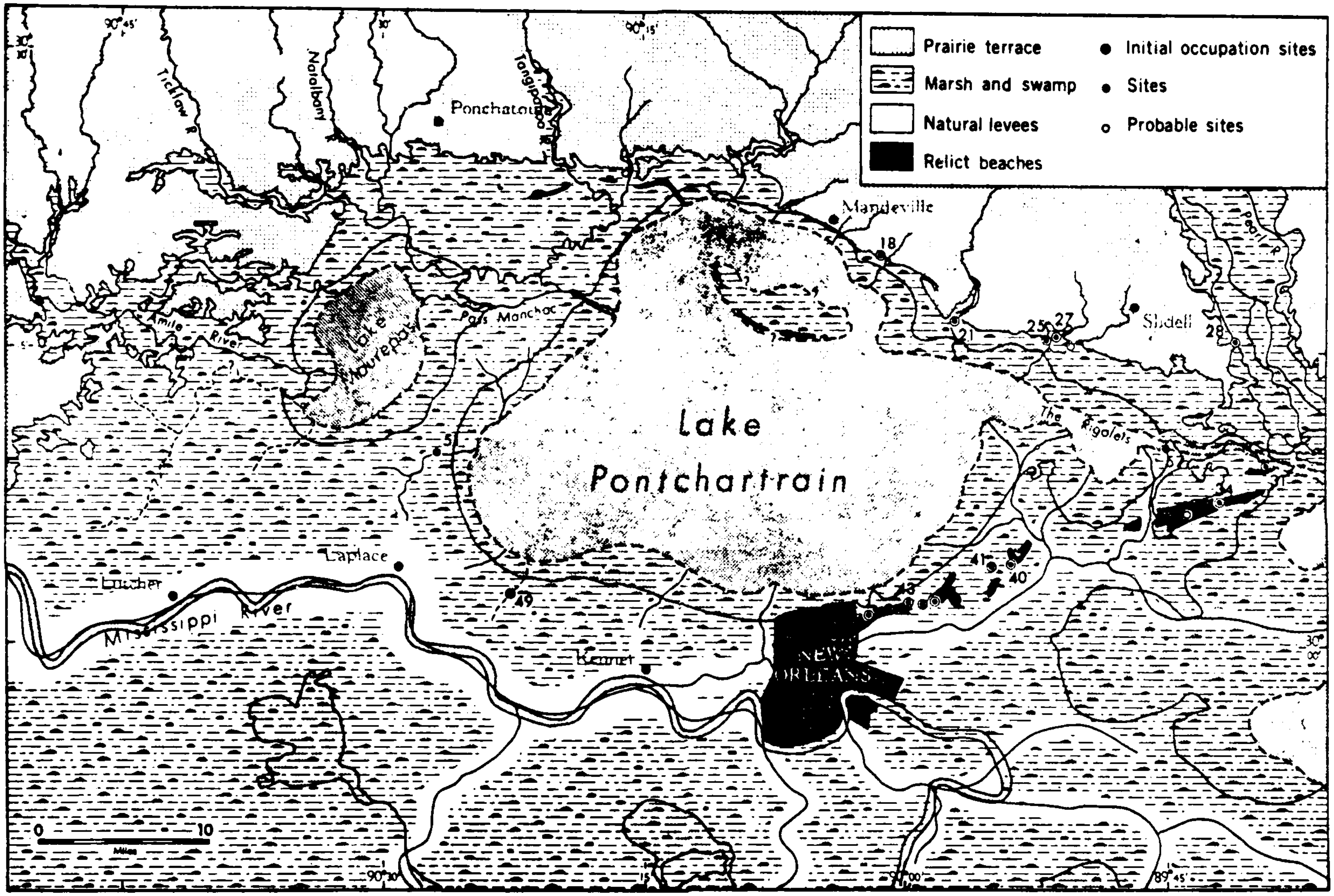

Figure 5A. The paleogeography of the Lake Pontchartrain area about 2000 to 2400 years ago (from Saucier 1963).

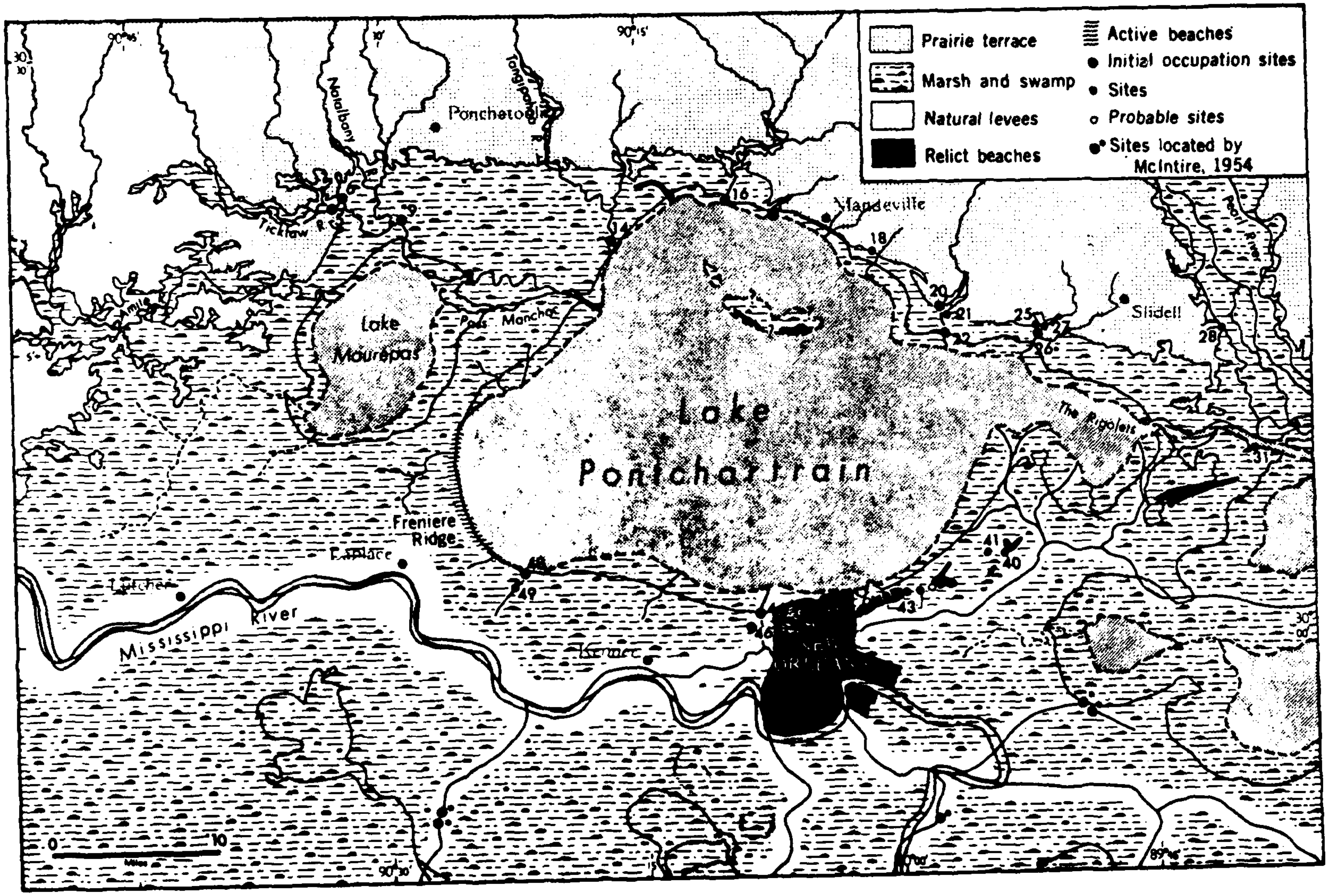

Figure 6A. The paleogeography of the Lake Pontchartrain area about 1400 to 1800 years ago (from Saucier 1963).

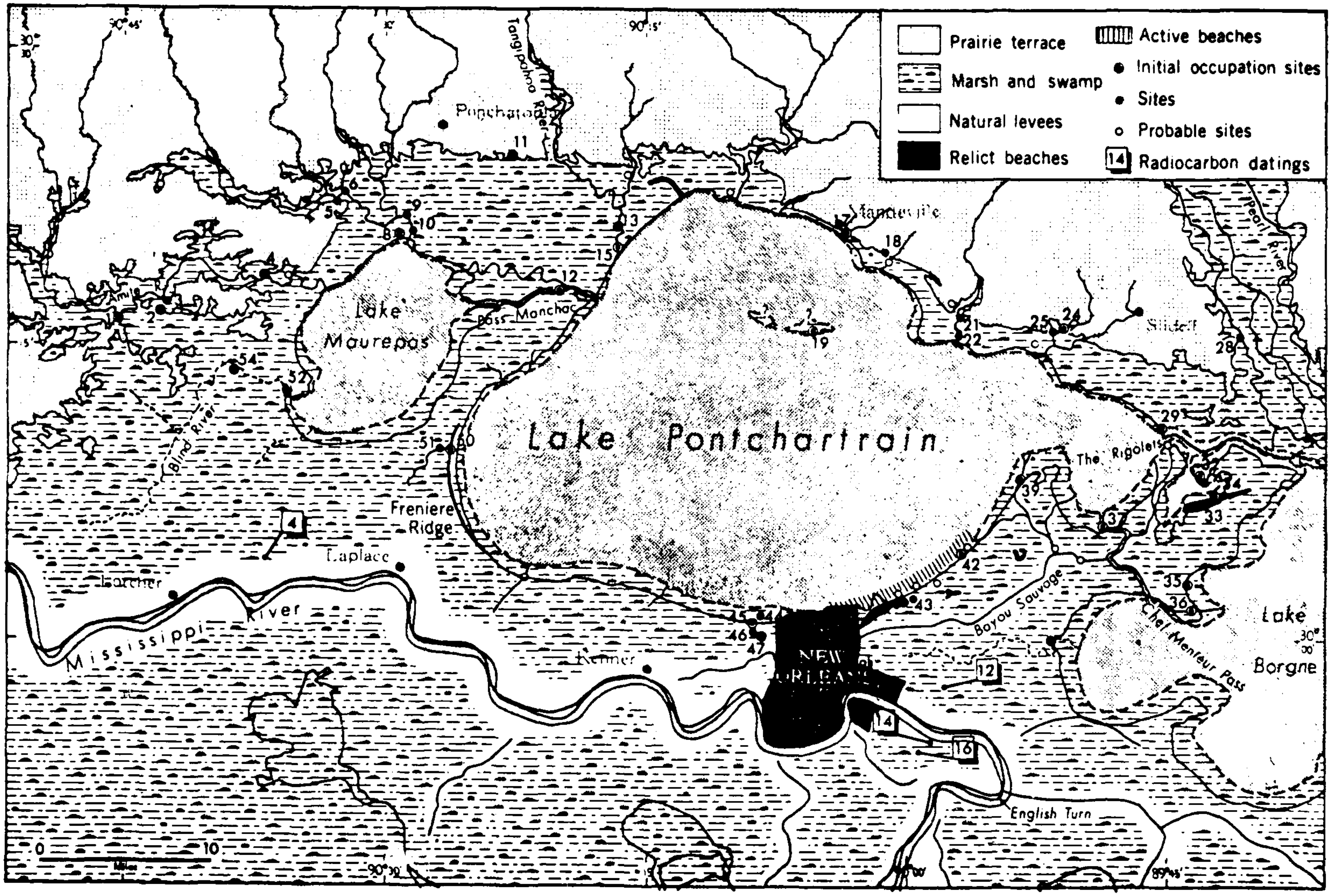

Figure 7A. The paleogeography of the Lake Pontchartrain area about 600 to 1400 years ago (from Saucier 1963).

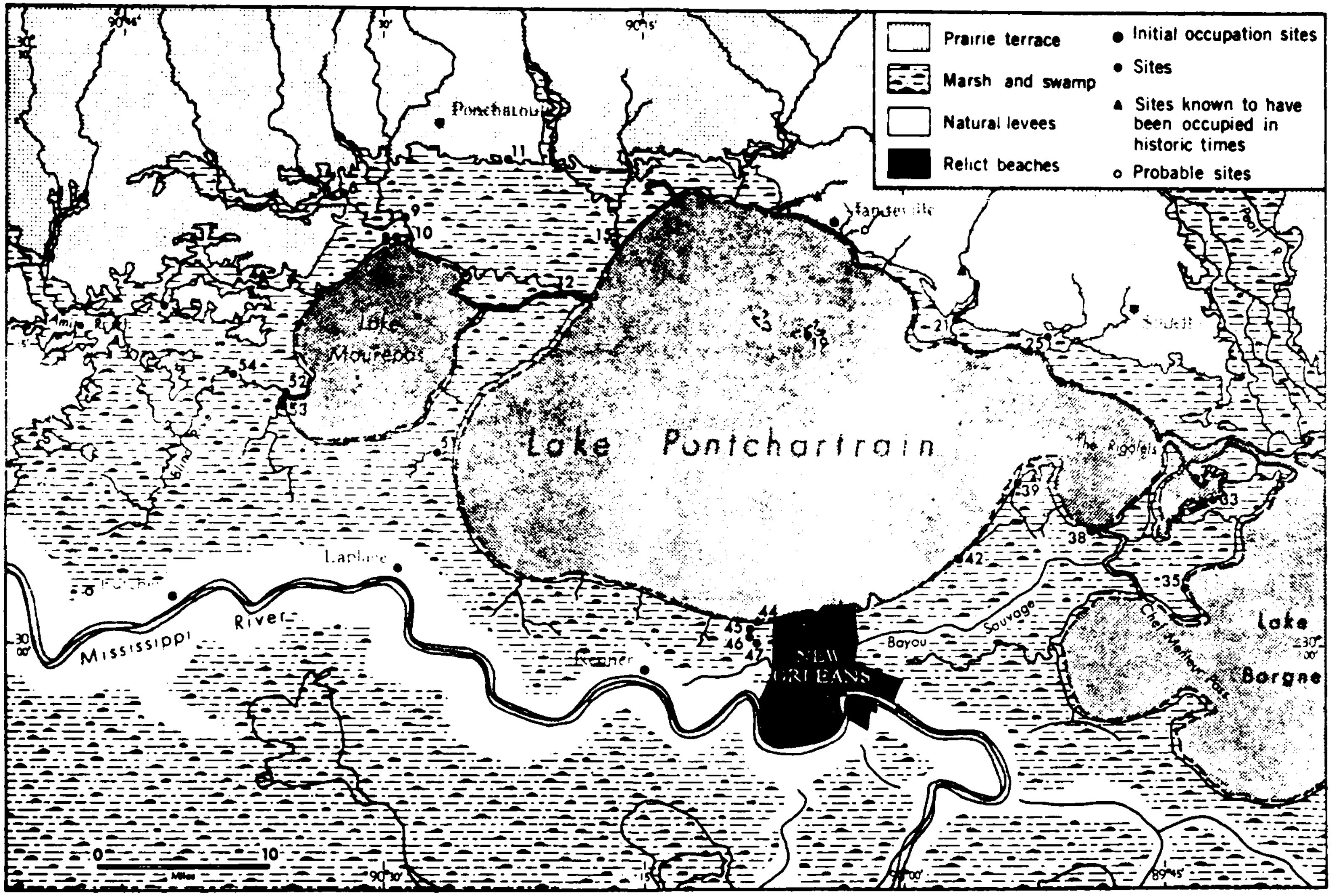

Figure 8A. The paleogeography of the Lake Pontchartrain area about 300 to 600 years ago (from Saucier 1963).

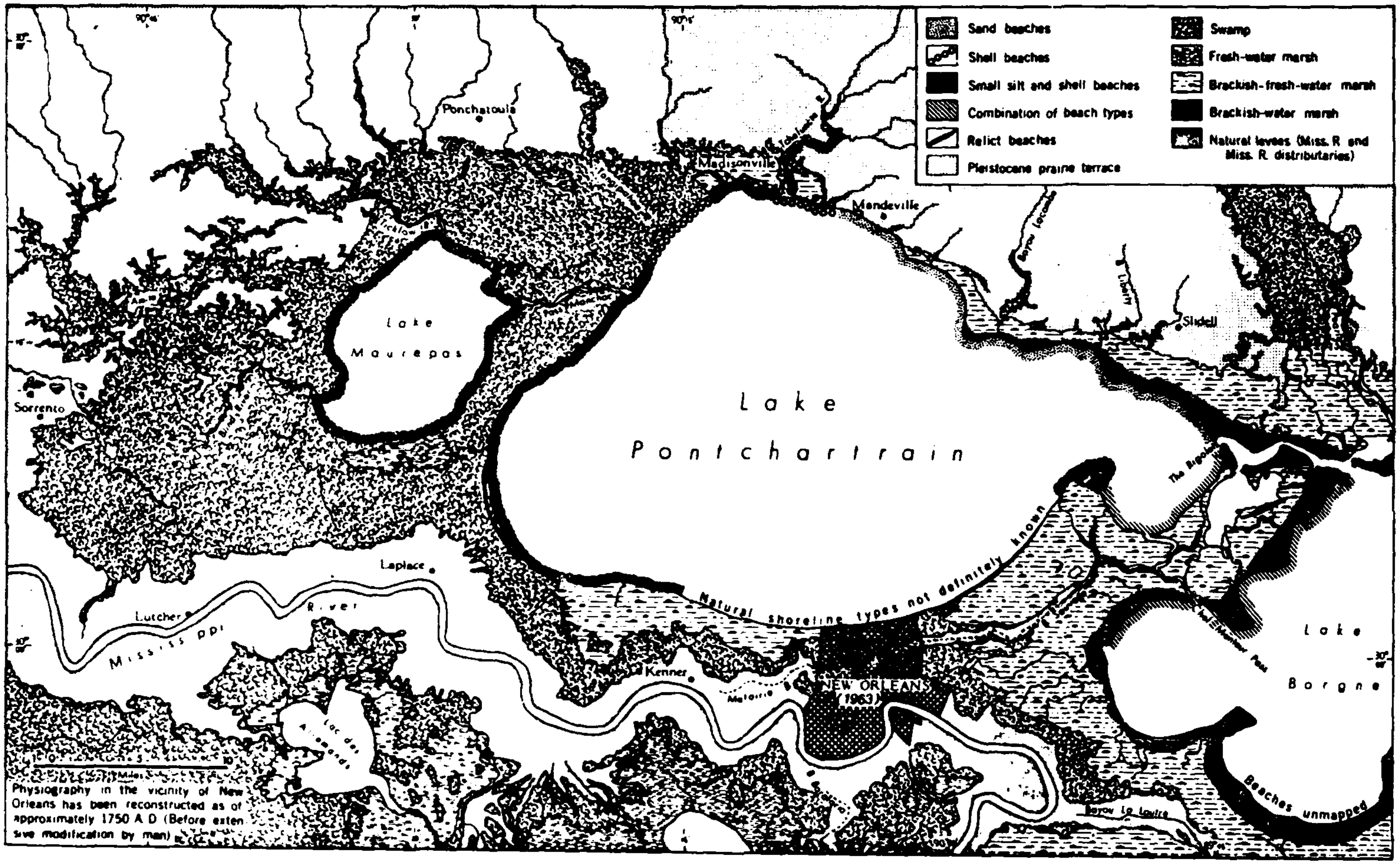

Figure 9A. The physiography of the Lake Pontchartrain area about 1750 (from Saucier 1963).

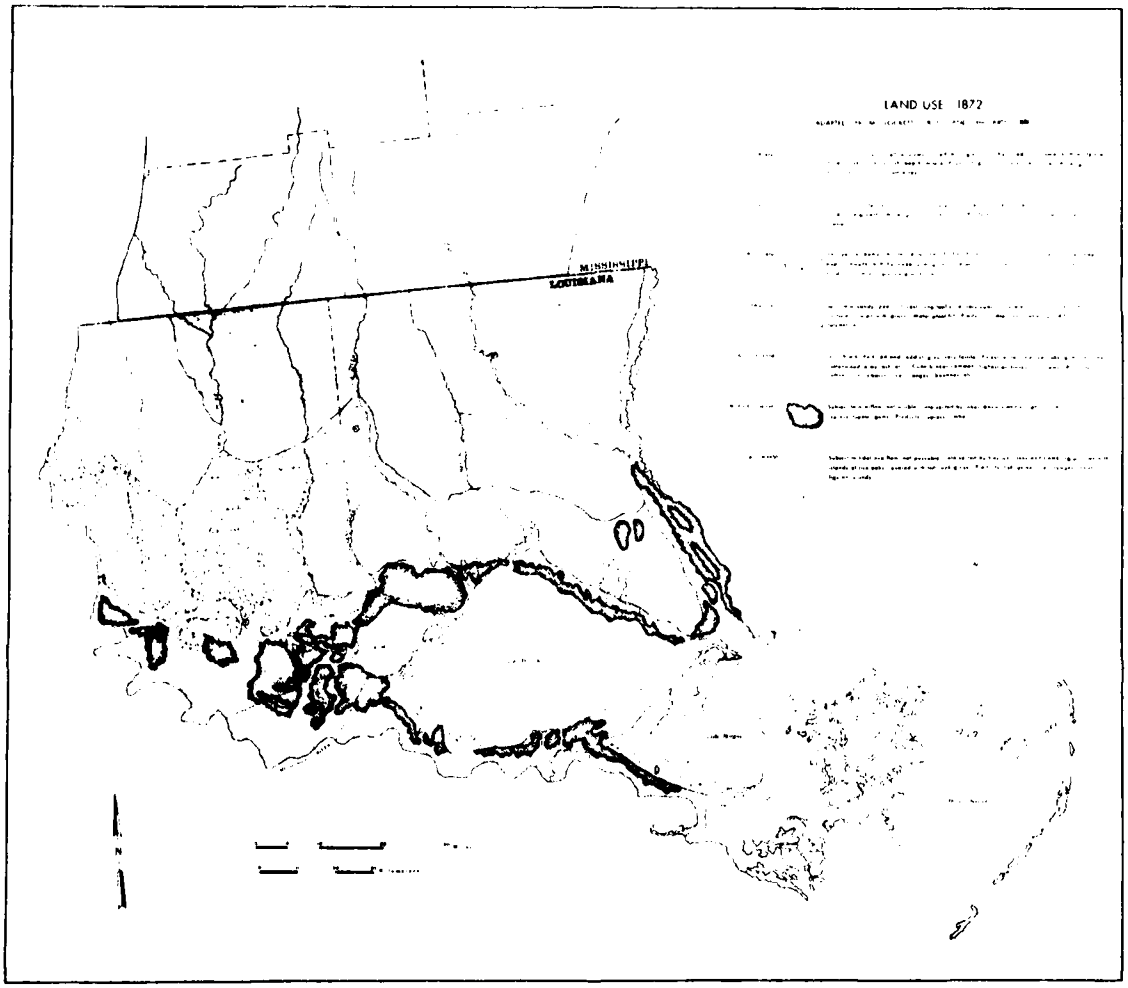

Figure 10A. Land use in the Lake Pontchartrain area in 1872 (adapted from Lockett 1872).

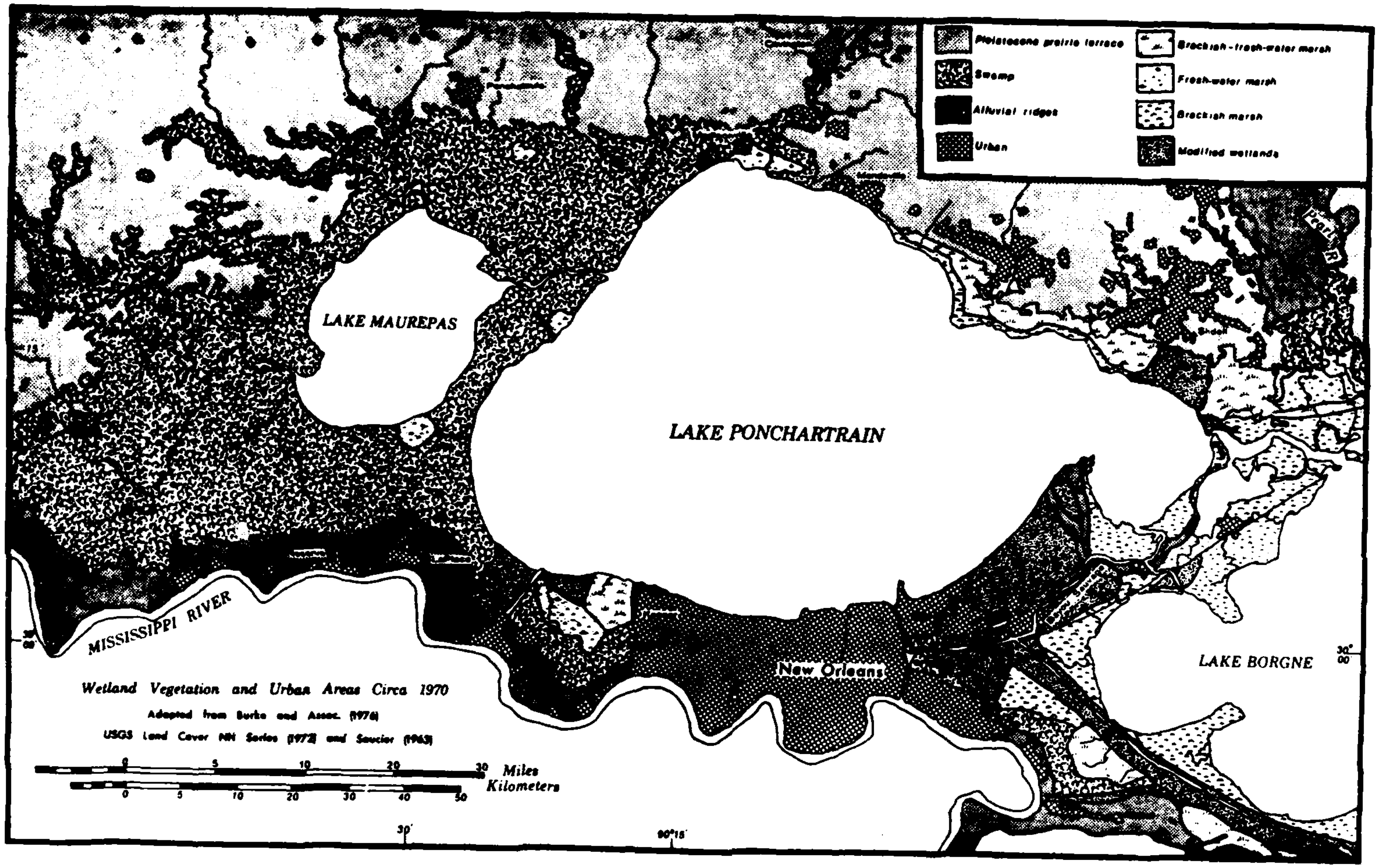

Figure 11A. Land use in the Lake Pontchartrain area around 1970 (adapted from Burke and Assoc. 1976, USGS Land Cover NH series for 1972 and Saucier 1963).

Partial view of shell-loading apparatus on dredge

Chapter 19

URBANIZATION, PEAK STREAMFLOW, AND ESTUARINE HYDROLOGY (LOUISIANA)

by

R. Eugene Turner and Judith R. Bond

ABSTRACT

Increased drainage on the Amite River watershed (Louisiana) through devegetation and subsequent urbanization has resulted in a greatly increased flood frequency and flood potential. The impact on the coastal wetland ecosystem is an altered hydrological regime in the swamp, more intense flushing rates of the nearby brackish lake (Lake Maurepas), and perhaps an altered nutrient loading to the estuary.

INTRODUCTION

The Lake Pontchartrain (Louisiana) watershed has undergone considerable land use changes in the last 50 years (Turner and Bond, Chapter 18). Of interest here is the effect of urbanization on the hydrology of the Amite River and its probable effect downstream. This river represents 50% of the freshwater source for Lake Pontchartrain (Swenson, Chapter 4), a large, shallow (2 m) coastal estuary, and is the major freshwater supply for the adjacent and slightly brackish Lake Maurepas. The latter, in particular, is surrounded by coastal wetlands whose characteristics, we expect, are strongly influenced by a changing hydrological regime (Gosselink and Turner 1978), which may also affect coastal fisheries (Turner 1979). Our study documents an example of the increased flood frequency, magnitude, and decreased duration within the

lower portion of the Amite watershed as a result of changing land uses in the Baton Rouge, LA, urban environs. This one example may encourage others to examine similar inter-ecosystem couplings (land-river-estuaries) that are perhaps influenced by changing upland land uses.

MATERIALS AND METHODS

The two major rivers near Baton Rouge, Louisiana, are the Comite and Amite Rivers; the former drains into the latter south of Baton Rouge at Denham Springs and then empties into Lake Pontchartrain via Lake Maurepas. An unusual circumstance of this study is that the present urban area of Baton Rouge is surrounded by land that has remained in a similar vegetational cover for the last three decades (Fig. 1). From 1950 to 1975, the urban population increased ten times. The construction of drainage culverts, pavement, levees and ditches, and stream channelization has accompanied the expansion into the formerly agricultural and forest lands. We examined the records of four United States Geological Survey (USGS) stream gages located within the watershed. Two gages were considered control stations above the urban area: one is at Olive Branch, LA, on the Comite River; the other, at Darlington on the Amite River. Most of the runoff from Baton Rouge enters upstream from the gaging station at Comite, LA, on the Comite River. The Comite River joins the Amite River upstream from the gaging station at Denham Springs, LA.

The annual flood frequency was estimated by counting all rapid rises in river discharge that approached bankfull conditions (approximately eight times the average flow). The peak flood discharge for 1948 to 1978 was determined for each of four gaging stations (Fig. 1) where the Amite River discharge at Denham Springs exceeded or approached flood

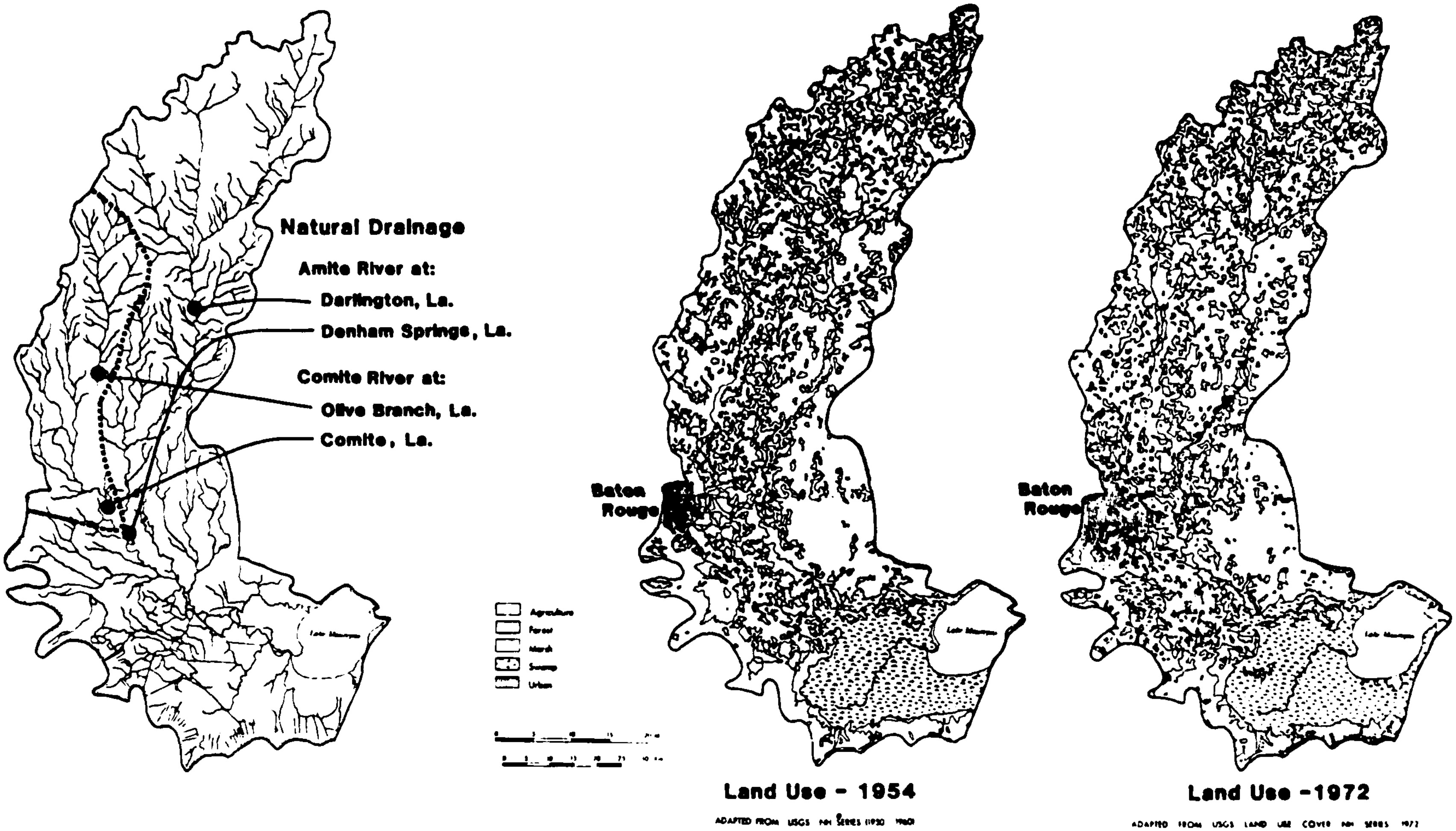

Figure 1. (A) The Comite River watershed is outlined by the dashed line. Land use for the area in 1954 (B) and in 1972 (C) was digitized; no significant net changes in non-urban areas above Baton Rouge were evident.

conditions (424 m^3/sec; 15,000 cfs). Annual flood recurrence intervals were also plotted for each station for the period 1951 to 1964 and compared to that of 1965 to 1977.

RESULTS

The peak stream discharge at both control sites has remained constant or decreased slightly from 1950 to 1970 (Table 1). It has increased about 0.38% per year in the same period on the Amite River at Denham Springs but 2.3% per year near Baton Rouge. The difference is expected because the Comite River is diluted approximately 1:3 when it joins the Amite River at Denham Springs, a town that has experienced minor land use changes in this period. The frequency of floods has also increased (roughly 50%) at the experimental but not at the control areas.

Because rain does not fall evenly over a watershed, an analysis that eliminates the areal and annual variations in rainfall is desirable to predict the annual increase in flood potential or flood crest discharge; this is expressed as follows:

$$\text{Flood Crest Discharge or Flood Potential} = \frac{\text{peak discharge at Comite, LA}}{\text{peak discharge at Denham Springs, LA}} \qquad \text{(Eq. 1)}$$

A linear regression of the ratio vs. year from 1948 to 1978 is shown in Figure 2. This ratio has been increasing steadily. It is apparent that either the Comite River discharge is increasing or the Amite River peak flood discharge is decreasing. But no increase or decrease in peak flood discharge from the control areas (at Darlington or Olive Branch) is evident. The obvious explanation is that the changing land uses of the Baton Rouge area are resulting in more rapid storm water drainage into the Comite River. Flood discharges, hence heights, are thereby

Table 1. A Comparison of the Peak Flood Discharge of the Amite and Comite Rivers in Two Control Areas (a and b) and Two Urban Areas Near Baton Rouge, LA[1]

Area (Watershed Area)	Percent change (1951-1960 vs 1961-1970)
a. Comite River at Olive Branch, LA ($145\ mi^2$)	-2
b. Amite River at Darlington, LA ($580\ mi^2$)	-6
c. Comite River at Comite, LA ($284\ mi^2$)	+23
d. Amite River at Denham Springs, LA ($1280\ mi^2$)	+3.8

[1]For floods where the discharge of the Amite River at Denham Springs, LA, is greater than 424 m^3/sec (15,000 cfs). These data were taken from records collected and maintained by the United States Geological Survey and the Louisiana Department of Public Works.

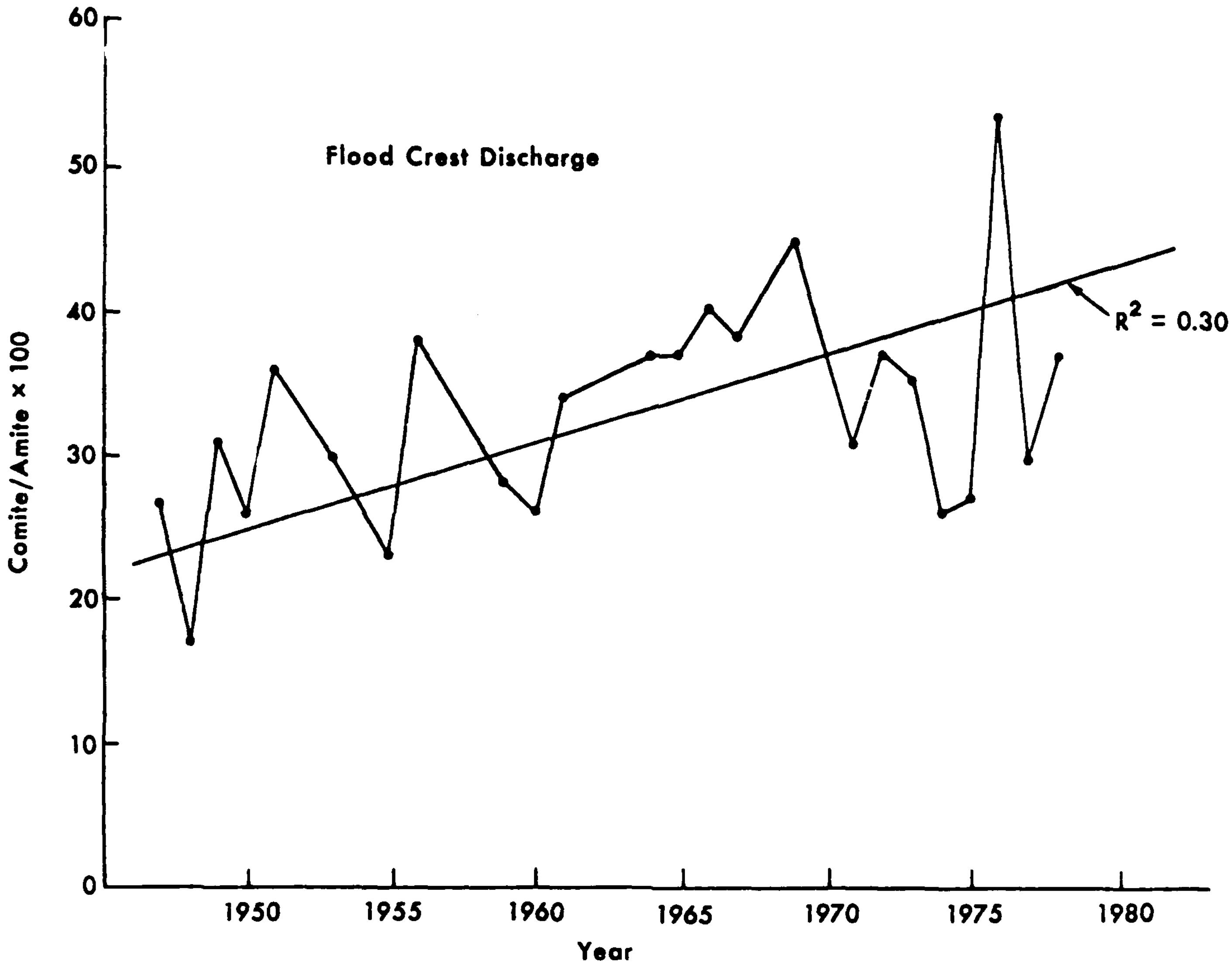

Figure 2. The peak stream discharge of the Comite River at Comite, LA, as a percentage of the peak stream discharge of the Amite River at Denham Springs. Some years experienced no floods; other years had several and were averaged. A linear regression for the period 1948-1978 is also shown.

increased at Comite, LA, as well as downstream on the Amite River at Denham Springs.

The relative increase in flood potential during this period can be estimated for any major storm. Assume that the flood potential has remained constant except for the urbanized portion of Baton Rouge (e.g., Table 2). The peak crest discharge at Denham Springs (A) is therefore equal to

$$A = U + C \qquad \text{(Eq. 2)}$$

where U is an unchanged upstream component, and C is the peak discharge from the Comite River. From 1948 to 1978, C/A increased from 0.25 to 0.42 (Fig. 2). If we assume then that $A_{1948} = 1$, and know that $C/A = 0.25$, then $C_{1948} = 0.25$ and $U_{1948} = 0.75$. In 1978, U remained unchanged and equal to 0.75, but $C/A = 0.42$. Substituting in equation 1, then,

$$A = 0.42A + 0.75 = 1.20$$

In other words, the potential peak flood discharge of the Amite River has increased 29% from 1948 to 1978. Using a similar analysis, I estimate that the potential floods of the Comite River at Comite have increased 37% in the same period.

A flood recurrence interval for each gaging station is in Figure 3. Two periods of record were graphed, 1951-1964 and 1965-1977. A comparison of each period shows that the lines are unchanged for the control sites but higher at the two experimental sites in the more recent period. The divergence from a straight line at the extreme right (high flow periods) was expected since: (1) soil infiltration and runoff rates change when soils become saturated, and (2) the few years of available records. These graphs illustrate, in another way, the changes at the experimental sites relative to the control sites.

Table 2. Flood Frequency on the Amite and Comite Rivers in Two Control Areas (a and b) and Two Urban Areas Near Baton Rouge, LA*

Area	Number of Annual Floods 1951-1960	1961-1970	1971-1978
a. Comite River at Olive Branch, LA	2.4	2.6	2.6
b. Amite River at Darlington, LA	1.6	2.2	2.6
c. Comite River at Comite, LA	3.8	3.9	5.3**
d. Amite River at Denham Springs, LA	1.2	1.8	1.7

*These were determined by approximating the flood to be 8 x the annual average discharge; a = 2,000 cfs, b = 7,000 cfs, c = 3,000 cfs, and d = 15,000 cfs.

**This value was significantly higher at the 5% level than either earlier period.

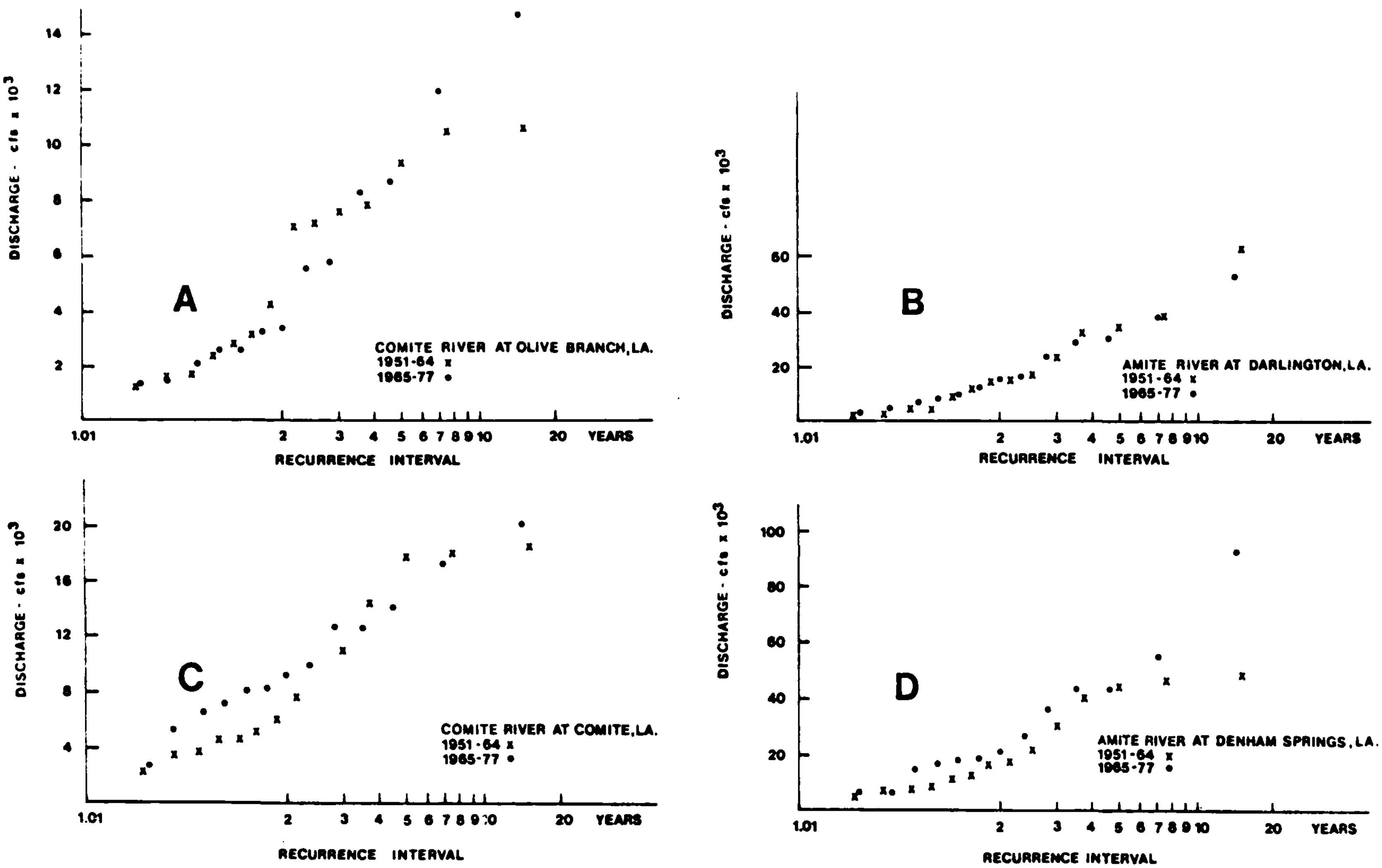

Figure 3. Flood recurrence graphs for the two control areas (A and B) and two urban areas near Baton Rouge, Louisiana, (C and D) for 1951-1964 and 1965-1977.

I could find no differences in minimum discharge or annual average discharges between control and experimental sites. Apparently, the rate but not the amount of water runoff was influenced by urbanization in Baton Rouge. The peak discharge during a storm today must therefore be more sharply defined than in the 1950's.

DISCUSSION

Urbanization in Baton Rouge has resulted in increased peak flood discharges of 30 to 40%, more frequent flooding, and a more sharply defined flood discharge vs. time relationship for the Amite River but not in altered annual average discharges. Elsewhere, others have arrived at similar conclusions. For example, Anderson (1970) relates that in northern Virginia, urbanization increased flood peaks by a factor of 2 to 8, depending on the local drainage density. Comparable increases for the same reason were found by Yorke and Herb (1971) for Maryland; Wilson (1967) for Mississippi; and Rantz and Harris (1964) in California. Additional influences of increased runoff are the changes in sedimentation, channel morphology, and mean velocity (Guy and Ferguson 1962, James 1965, Knox 1977).

The changes in river flows described here influence not only local stream bank erosion rates and flooding but also the biology of the wetlands downstream. The chemistry of variously flooded soils is quite different from well-drained soils, and it in turn affects the distribution abundance and diversity of flora and fauna (Gosselink and Turner 1978, Brown et al. 1978). If stream nutrient concentration are closely related to discharge rates but in a nonlinear manner, then the nutrient loading rates to the estuary are affected. Also, phytoplankton communities are influenced by changing dilution rates (Deudall et al. 1977). The average

flow of the Amite River for 1949-1977 was about 25,000 cfs, and urbanization has led to an apparent increase in the peak flow of 30%. The volume of Lake Maurepas is about $5 \cdot 10^8 m^3$. For a one-day period, the increased flushing time due to the increased peak flow is +30%, or about equivalent to +3% of the volume of the lake; during an exceptionally high flow, it may reach +10%.

This may be an important factor to examine elsewhere. Lake Maurepas is quite large (236 km^2), but there are many coastal areas where urbanization and devegetation have occurred in watersheds next to coastal inlets of sufficiently small size to have their turnover time considerably influenced by moderately increased river flow. The leveeing of the Mississippi River, for example, has also led to increased peak river discharge and height, changes in channel morphology, and subsequent coastal wetland losses (Belt 1975, Craig et al. 1979). This is not to say that there are not other considerations for such projects and developments but rather to point out that there may be some unexpected complications downstream.

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